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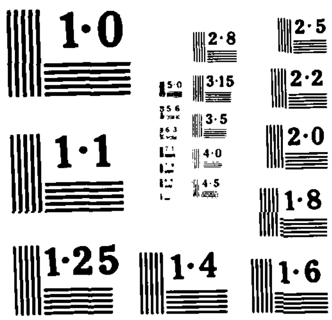

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INTEROPERABLE COMMERCIAL SATELLITE SYSTEM (ICSS) SPECIFICATION

Draft Report 168
Task MSO85-2

November 1985

Prepared by M/A-COM LINKABIT, Inc.
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Submitted to
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Center for Command and Control,
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Arlington, VA 22204

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CENTER FOR COMMAND AND CONTROL, AND COMMUNICATIONS SYSTEMS (C^4S)

" EXCELLENCE IN C^3 SYSTEMS FOR NATIONAL DEFENSE"

INTEROPERABLE COMMERCIAL SATELLITE SYSTEM (ICSS) SPECIFICATION

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DEFENSE
COMMUNICATIONS
AGENCY

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DEFENSE COMMUNICATIONS AGENCY

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CHAPTER 1. SCOPE

1.1 PURPOSE

This specification establishes the performance, design, development, and test requirements for an Interoperable Commercial Satellite System (ICSS). The purpose of the ICSS is to implement the Commercial Satellite Survivability (CSS) initial architecture, which is limited to large C-band satellite assets with CONUS coverage and augmentation of the Public Switched Network (PSN). Later updates of the architecture will expand the area of consideration to include other C-band satellite assets as well as Ku-band and mobile satellite assets. These updates will be based on needs identified from other ongoing architectural efforts, such as the final Nationwide Emergency Telecommunications System (NETS) definition. Complete implementation of the ICSS will entail successive stages of definition and refinement. Each stage drives an update to the architecture and the subsequent program definition.

1.2 BACKGROUND

The Federal Government relies heavily on the communications services provided by the commercial satellite systems that constitute an important element of the national telecommunications infrastructure. These systems not only provide routine services but are also needed to support critical civil government and military communications under day-to-day as well as emergency conditions.

Executive Order (E.O.) 12472, "Assignment of National Security Emergency Preparedness Telecommunications Responsibilities," directs the National Communications System

(NCS) to ensure that a responsive, survivable national telecommunications framework is developed to satisfy high-priority telecommunications requirements under all circumstances. This national framework is to combine hardness, redundancy, mobility, connectivity, interoperability, restorability, and security to obtain national security emergency preparedness (NSEP) telecommunications survivability. Commercial satellite and terrestrial telecommunications resources will play a critical role in providing the framework in CONUS.

An initiative to enhance the surviviability of commercial satellite systems in accordance with E.O. 12472 and complementary policy guidance contained in National Security Decision Directive-42 (NSDD-42), "National Space Policy," and NSDD-97, "National Security Telecommunications Policy," has been developed by the Office of the Manager, NCS (OMNCS), in consultation with the President's National Security Telecommunications Advisory Committee (NSTAC). Implementation of planned CSS enhancements will increase the NESP responsiveness and availability of commercial satellite systems and promote satellite carrier interoperability, redundancy, connectivity, and restorability.

Commercial satellite communications became one of the three primary issues established for consideration by the NSTAC, which was formed in September 1982 under E.O. 12382 to provide information and recommendations to the President regarding national security and emergency preparedness telecommunications matters. A CSS Task Force was established under the NSTAC as a forum for a joint industry/government assessment of commercial satellite initiatives. The task force report, presented on May 20, 1983, was approved and submitted to the President with a recommendation for implementation. On February 21, 1983, the President endorsed the NSTAC's

recommendations and included in his direction that "near-term enhancements to assure the capability to coordinate the restoration of commercial satellite communications systems in support of Government-wide NSEP requirements should be pursued immediately."

When the NSTAC recommendations were forwarded to the White House, the Secretary of Defense in an accompanying letter agreed with the importance of the initiatives. He directed the Defense Communications Agency (DCA) to be the focal point to prioritize the initiatives and determine who should pursue their implementation. This direction resulted in the publication of the Commercial SATCOM Initiative (CSI) Program/Plan in November 1985 (Ref. 1) and the development of this system specification.

CHAPTER 2. APPLICABLE DOCUMENTS

This chapter sets forth the documents that are applicable to the ICSS specification.

2.1 GOVERNMENT DOCUMENTS

- Commercial Satellite Survivability (CSS) Architecture, DCA/MSO, June 1985
- Commercial Satellite Survivability (CSS) Program/Plan, DCA/MSO, November 1985
- Nuclear Susceptibility of U.S. Domestic Commercial Communications Satellites, The Aerospace Corporation, Report No. TOR 0084A (5416)-2, 18 April 1985
- Human Engineering Guide to Equipment Design (Revised Edition), Harold P. Van Cott and Robert G. Kinkade, editors, McGraw-Hill Company, 1972.

2.2 NON-GOVERNMENT DOCUMENTS

- AT&T Technical Advisory #32, "D3 Compatibility"
- Survivability Assessment of the Public Switched Network Augmented by Commercial Satellite Connectivity for Scenario No. 5, AT&T Briefing, October 1985
- "Satellite Locations--1984," Proc. IEEE, Walter Morgan, November 1984
- Enhanced TT&C Interoperability Among Commercial Satellite Systems, Final Report, RCA Astro Electronics, September 27, 1985
- Technical Operating Report for the Interoperable Telemetry, Tracking and Command System, Hughes Space Communications Group, September 30, 1985.

CHAPTER 3. REQUIREMENTS

3.1 SYSTEM DEFINITION

3.1.1 General Description

The ICSS consists of a number of elements which, together, provide survivable interswitch trunking between pairs of PSN class 4 (or equivalent) switches using a combination of terrestrial and satellite facilities. This connectivity is provided on a demand basis through a control structure that is also part of the ICSS.

The ICSS is based on the existence of at least one surviving commercial satellite, a control capability for that satellite, several general service earth terminals, and PSN switches. Figure 3-1 illustrates the basic concept of providing replacement interswitch trunks between PSN switching elements using interoperable satellite earth terminals.

The ICSS encompasses augmentation of the PSN by providing pre-engineered T1 trunks between surviving toll switches over interoperable commercial satellite channels. The earth station enhancements are structured to provide both cost-effective initial augmentation of the PSN and compatibility with planning for future NETS applications.

The ICSS provides for reconnecting isolated switches through gateways into the PSN to augment connectivity between poorly connected switches and richly connected switches. Three richly connected switches have been identified as potentially suitable gateways, based on geographic diversity, proximity to earth stations, and proximity to serving Signal Transfer Points

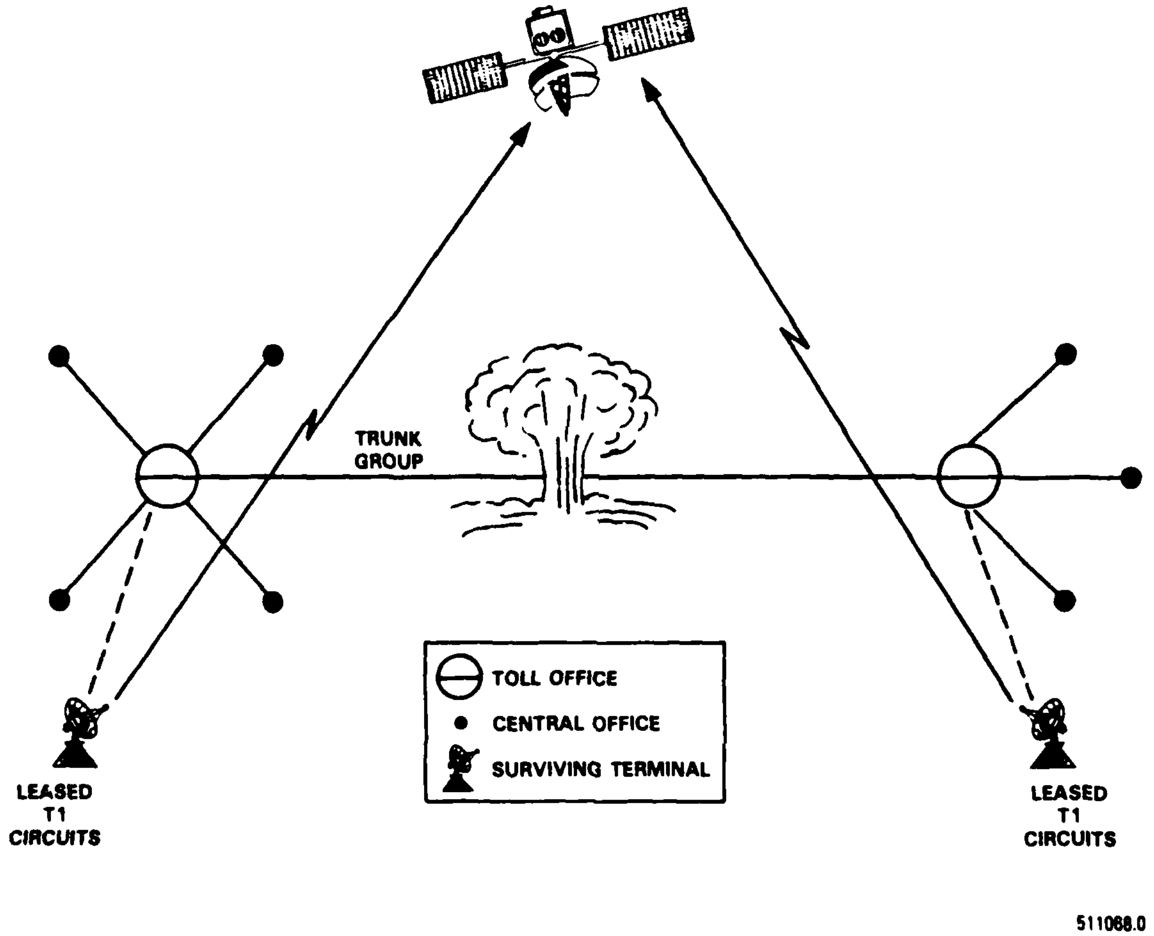

Figure 3-1. Concept of Earth Station/PSN Interconnection

(STPs). An earth station is selected near each gateway switch to provide satellite channel trunks to corresponding earth stations near isolated switches. The earth stations are connected to their respective switch location by T1 trunks. At locations with no suitable surviving earth station, low-cost fixed terminals will be neede . This gateway arrangement will enable selected calls between isolated switching centers and the intact PSN to be routed over pre-engineered T1 trunks via terrestrial links to earth stations and satellite links between the earth stations.

The augmentation plan provides a baseline configuration that uses the three gateways to connect 13 isolated switches, each having two or three diverse T1 routes. Appendix A (bound separately) shows the locations of switches and corresponding earth stations as well as the required connectivity.

Communications interoperability between different satellite earth terminals will be achieved at three levels: radio frequency (RF), intermediate frequency (IF), and baseband. The RF/IF relates to the antenna and feed structure, tracking mechanism, high-power amplifier (HPA), up/down converters, and low-noise amplifier (LNA). Baseband relates to the modem, multiplexing and demultiplexing equipment, and the terrestrial interface to the PSN. This concept has been developed to the point of identifying eight architectural components as indicated in the June 1985 CSS architecture report (Ref. 2). The eight components are:

- Plans and procedures
- Command link protection
- Telemetry, tracking and control (TT&C) interoperability
- Communications interoperability
- Network monitoring and control
- Low-cost earth terminals

- Physical security
- Electromagnetic pulse (EMP) considerations.

3.1.1.1 Plans and Procedures

ICSS is based on the surviving assets of different common carriers. Therefore, intercompany as well as intracompany emergency plans are required for the National Coordinating Center (NCC) and the common carriers to support ICSS communications requirements in emergencies and for testing periods. The plans and procedures must contain sufficient detail to facilitate long-haul connectivity restoration among selected high-priority users. This system specification implies the existence of such plans and procedures, but details have not yet been developed. Section 3.1.6 outlines the assumed procedures to the extent that they affect the technical details of this specification.

3.1.1.2 Command Link Protection

The command signals for commercial satellites originate at TT&C ground stations and are transmitted to the satellite command receiver, where they are decoded and fed to the control equipment. Two types of threat to command links are of concern to commercial satellite operations. The first is the deliberate attempt to introduce false commands to the satellite to render the satellite inoperative or to commandeer satellite operation. The second type of threat is the use of interference signals to prevent the satellite from receiving proper commands. Implementing command link encryption is not part of the CSS program; rather, encryption will be implemented by each carrier as new satellites are launched. It is highly desirable that all links use compatible forms of protection for TT&C interoperability considerations.

3.1.1.3 TT&C Interoperability

Commercial domestic satellites are one of two types: spin-stabilized (Hughes) or three-axis stabilized (RCA). The control techniques for these two types of systems are not compatible. In addition, interoperability between similar systems does not exist. The ICSS will provide enhancements to two TT&C earth terminals (the details of which are now being determined) in order to provide intrasystem TT&C capability within each of the two families of satellites.

3.1.1.4 Communications Interoperability

Commercial satellite systems are varied in their use of frequency bands (both C and Ku), channelization, polarization, access schemes, and modulation methods. Because of this, there is an inherent lack of interoperability among the commercial satellite systems even among different facilities of the same carrier. Communications interoperability among the surviving portions of the commercial satellite systems can be realized with the least complexity and cost through limited modifications of only C-band terminals to provide RF and IF interoperability. Baseband interoperability will be provided through the use of compatible modems at each earth station. These modems will provide the standard T1 interface to terrestrial tail circuits that connect to the PSN switches, thus providing the required interswitch trunks.

3.1.1.5 Network Monitoring and Control

The purpose of the network monitoring and control capability is to provide the means to assess the availability of space and ground resources and to establish an orderwire

communications network among all participants including the surviving NCC function.

3.1.1.6 Low-Cost Earth Terminals

The PSN augmentation requirement calls for T1 connectivities at selected switch locations where access to a general service earth terminal is not considered practical. In addition, as part of the control structure of ICSS, the NCC function requires access to the orderwire network. These requirements will be satisfied by providing low-cost terminals at or near those locations.

3.1.1.7 Physical Security

Physical security for commercial satellite communications systems comprises the prevention of disruption or destruction of communications earth stations and satellite control facilities and the unauthorized access to, and control of, satellite systems. Because of the criticality of the satellite control facilities, the approach taken for the initial ICSS is to enhance the physical security of the selected TT&C sites only. (This system specification does not address the specific requirements for enhanced physical security.)

3.1.1.8 EMP Considerations

Electromagnetic pulses generated by high-altitude nuclear bursts pose a threat to the survivability of ground-based electronic equipment, including satellite communications terminals and TT&C facilities. Although validated data are lacking on the precise characteristics of such nuclear bursts and the resultant effects that they will have on equipment, measures have been developed to mitigate the effects of high-altitude EMP (HEMP) based on the results of full-scale simulation tests of facilities and components testing. These

methods can be applied to different degrees and in varying combinations to produce different levels of protection, with cost increasing with the amount of protection. At this stage, a low-cost strategy has been selected. The overall objective of this approach is to obtain some protection from HEMP effects while keeping costs down and maintaining a balance with other survivability measures. (This system specification does not specify the EMP considerations to be implemented, but does suggest areas where specific enhancements should be considered depending on actual cost on a per-site basis.)

3.1.2 Mission

The mission of the ICSS is to establish T1 connectivity between designated PSN switching nodes through the use of surviving commercial satellite spaceborne and ground assets in a post-nuclear attack environment. The scope of the initial implementation is limited to common carrier-owned C-band satellite assets with CONUS coverage and support of the PSN. Appendix A contains the details of the required connectivity. Follow-on implementation will be based on architectural updates, which will consider inputs from other ongoing architectural efforts, such as the DSN WESTHEM architecture and the final NETS definition, and specific point-to-point and special-user requirements. The systems to be considered will be expanded to include other C-band assets, such as dedicated or privately owned assets, and emerging services and technologies, including Ku-band and mobile satellite assets.

3.1.3 Threat

The threat to commercial satellite networks includes the physical destruction of ground segments, spoofing the control mechanisms, EMP effects on ground segments, nuclear effects on spacecraft, and the disruption of communications channels.

Table 3-1 summarizes the threat to commercial satellite systems.

Table 3-1. Potential Threat to Commercial SATCOM and Mitigation Approach

THREAT	IMPLICATION
• PHYSICAL ATTACK – SABOTAGE/TERRORISM – NATURAL DISASTER – CONVENTIONAL WAR – NUCLEAR WAR	• LOSS OF: – FACILITIES AND/OR CONNECTIVITIES – SATELLITE CONTROL – NETWORK CONTROL
• SPOOFING	• LOSS OF SAT OR SAT CONTROL
• EMP	• LOSS OF FACILITY CAPABILITIES
• SGEMP, TREE, TRAPPED ELECTRON EFFECT	• LOSS OF SAT CAPABILITIES
• JAMMING	• DENIAL OF COMMUNICATIONS
• SCINTILLATION	• DENIAL OF COMMUNICATIONS

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The threat sources that can contribute to physical destruction of ground segments span all conflict phases and include natural or man-made disasters, sabotage, terrorism, conventional war, and nuclear war. This can include attacks on communications facilities to deny connectivity and on satellite and network control facilities, affecting both technical and network control functions.

Nuclear war will likely result in large-scale collateral damage to commercial satellite networks. The general services C-band terminals and control facilities expected to survive an attack on CONUS (as indicated in Ref. 3) are fragmented and generally operate over different satellites and networks. Although the survivability analysis was completed for both the

C- and Ku-band terminals, the architecture deals only with a subset of the C-band terminals--which consists of general services (large) terminals. General services terminals were selected because they offer the greatest capability for the least cost.

The control subsystems are vulnerable to spoofing, or unauthorized entry, by relatively unsophisticated means. This can result in the disablement of the spacecraft or its commandeering for other uses.

Ground segments are vulnerable to the EMP effects from high-altitude nuclear bursts that are expected to accompany nuclear attack on the United States. Although the extent of these effects on communications and control terminals is unknown, EMP damage to terminals that survive blast and thermal effects is expected.

High-altitude EMP bursts as well as nuclear antisatellite (ASAT) attacks against military space targets will also affect commercial spacecraft through both prompt (system-generated EMP (SGEMP) and transient radiation effects on electronics (TREE)) and delayed effects of trapped electron phenomena.

The Air Force Space Division recently published results of an assessment on the survivability of commercial spacecraft, Nuclear Susceptibility of U.S. Domestic Commercial Communications Satellites (Ref. 4). The discussion below describes this technical assessment and relates the results to specific threat scenarios.

The Space Division study, based on low-altitude exoatmospheric nuclear events, showed that at radiation levels less than 10^{-4} Cal/cm^2, the current generation of Hughes HS-376 and RCA Series 3000 spacecraft will not suffer from TREE latch-up (burn out). This assessment is also true for the next

generation HS-393 and RCA Series 4000 systems. As illustrated in Figure 3-2, such levels correspond to that generated by a 1-Mt detonation at a distance of 10,000 km, or 14-deg separation on the orbital arc.

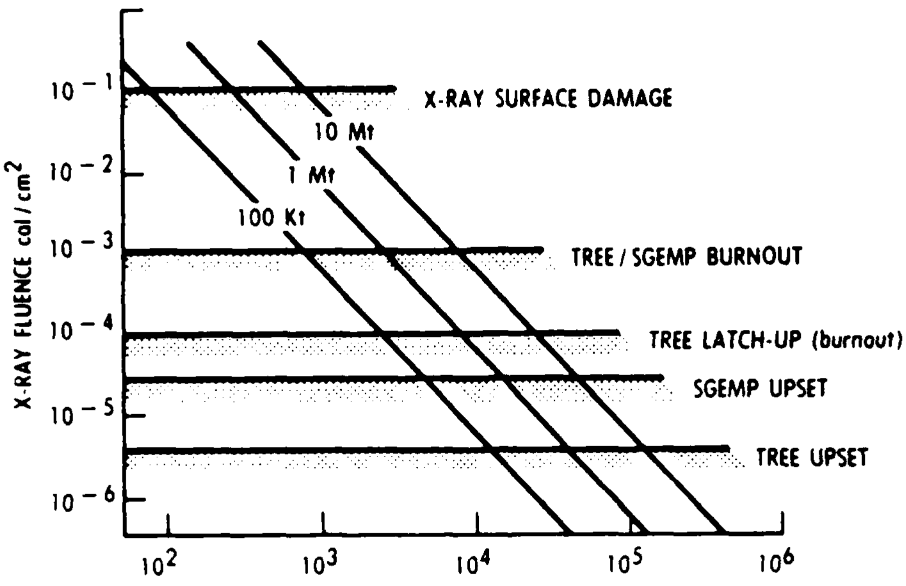

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Figure 3-2. Satellite X-Ray Effects Threshold

At intermediate radiation levels, between 10^{-4} and 10^{-6} Cal/cm^2, these spacecraft may suffer upsets. However, critical pieceparts will not be affected and all upsets can be corrected through self recovery or ground-based TT&C. For the trapped electron environment, the study concludes that existing and projected spacecraft are sufficiently protected against natural radiation so that some are expected to survive, although at a reduced but useful capability, for several months.

The time criticality for resetting upsets and placing the surviving satellites in a safe condition will vary depending on the upset. However, it is projected that upsets could be reset days after onset without permanent degradation.

A final threat is that of communications denial. Both communications and control channels are subject to disruption through intentional and unintentional jamming in all phases of conflict and in a nuclear-induced scintillation environment. There is no intent to mitigate trans-attack effects, so the trans-attack threat is disregarded. Jamming highly proliferated commercial communications satellite resources in pre-attack would be extremely difficult and is considered highly unlikely.

3.1.4 System Diagram

Figure 3-3 represents the top-level functional flow of the ICSS. It begins with a decision to activate the system, which has been in a standby mode. Because the state of the satellites and the earth stations is unknown, a designated control station must assess them. In the case of the satellites, the control station must be able to locate and perform rudimentary testing on each satellite to determine its suitability for use in establishing the network. One satellite will then be selected for use. For the earth stations, the control station must contact each one and receive information on its status and pass information as to the selected satellite to be used. Once notified, each earth station must readjust its antenna to point at the proper satellite and tune to the designated orderwire channel to await further instructions. In the meantime, a determination of the exact T1 connectivity requirements must be made and disseminated to the earth stations. With this information, the earth stations can tune modems to the required channels, verify the integrity of the new circuits, and release them for use by the PSN switches in

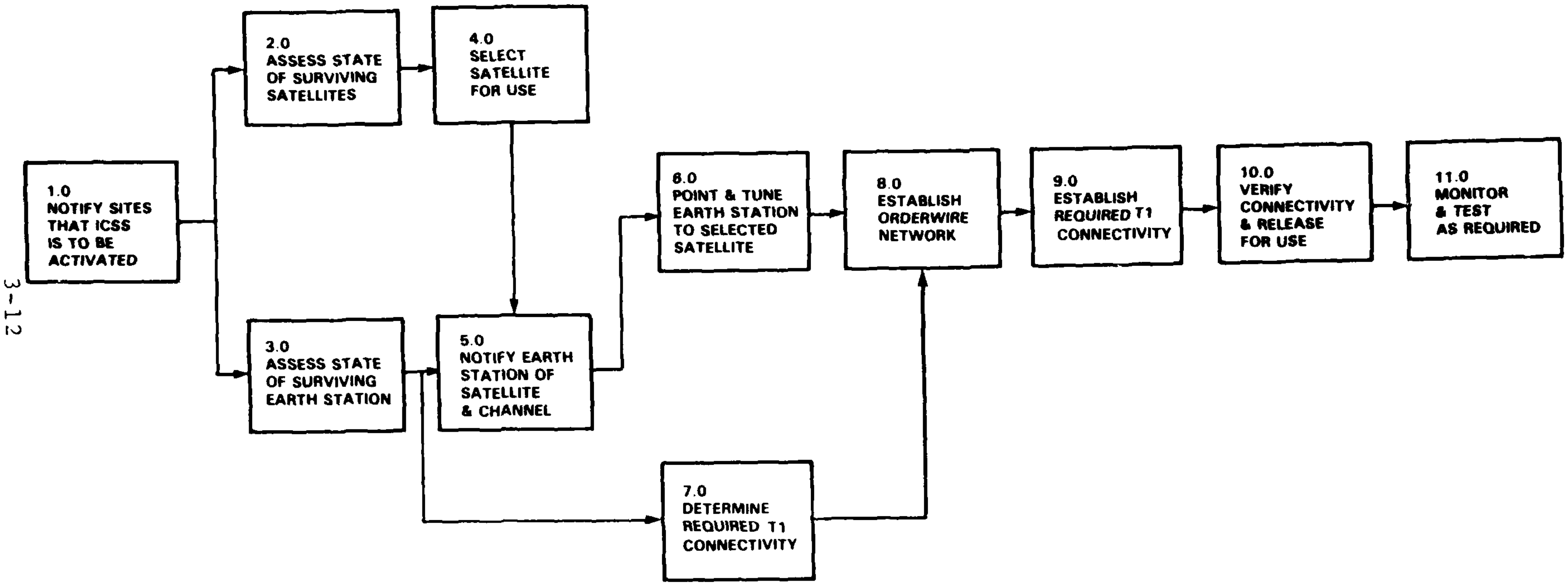

Figure 3-3. Top-Level Functional Flow of the ICSS

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routing critical calls. Once all this has been accomplished, the earth stations revert to a more passive role of monitoring the status of the new circuits and performing any testing that may be required for fault isolation and routine maintenance.

3.1.5 Interface Definition

This section specifies the functional and physical interfaces between the ICCS and other systems with which it must be compatible and between the functional areas within the ICCS. Figure 3-4 depicts and labels each of these interfaces, which are described below.

3.1.5.1 PSN to Terrestrial Link Interface (Interface A)

The PSN to terrestrial link is a DS1 interface as defined in the AT&T Technical Advisory #32, "D3 Compatibility" (Ref. 5). The interface must be compatible with the 1.544-Mbps DS1 line format, consisting of twenty-four 8-bit words and one framing bit, for a total of 193 bits per frame, and with a sampling rate for a message channel of 8000 times/sec. The electrical characteristics of the PSN to terrestrial link interface are:

- Line Rate: 1.544 Mbps
- Line Code: Bipolar
- Base to Peak Height: 3 ± 0.3 volts
- Pulse Height Imbalance: ±0.3 volts
- Rise and Fall Times: 80 nsec, maximum
- Pulse Density: Not more than 15 consecutive zeros
- Receiver Signal Level: 1.5 to 3 volts base to peak.

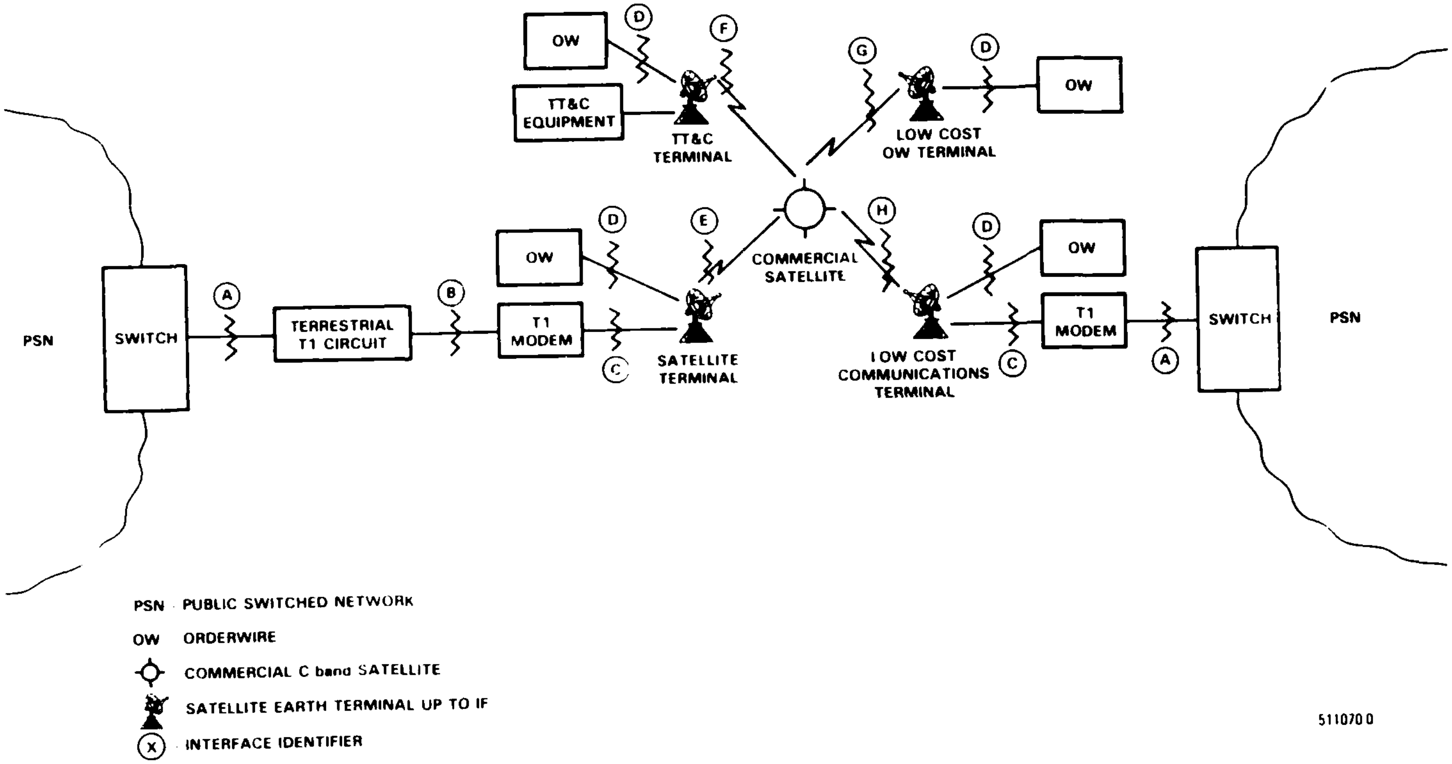

Figure 3-4. Interface Definition

The PSN to terrestrial link interface physical characteristics are:

- T1 Interface: 37 pin, D type
- Level: DS-1.

3.1.5.2 Terrestrial Link to Modem Interface (Interface B)

The characteristics for Interface B are:

- Input/Output Data Rate: Bell System Standard T1 rate of 1.544 Mbps
  - Uncoded: 2 x baud rate
  - Coded: Uncoded data rate x code rate
- I/O Data: Standard DS1 levels, 37 pin, D-type connector
  - Remote Interface: RS-232 levels, 25 pin, D-type connectors.

3.1.5.3 Modem to I/F Patch (Satellite Earth Terminal) Interface (Interface C)

The modem to satellite earth terminal interface will be at a standard 70-MHz intermediate frequency with electrical and mechanical interfaces as follows:

- Modulator
  - Connector: BNC
  - Output: -5 to -30 dBm, 50 Ω, or 75 Ω factory set, 2:1 VSWR maximum
  - IF Range: 52.000 MHz to 88.000 MHz, 5-kHz steps generated by an internal synthesizer
  - Data Clock: External (data rate $\pm$50)

- Demodulator
  - IF Range: 52.000 MHz to 88.000 MHz, 5-kHz steps generated by an internal synthesizer
  - Acquisition Range: ± 0.10 x baud rate, up to ± 35 kHz will acquire at E_s/N_o of 0 dB or greater
  - Acquisition Time: Less than 1 sec for E_b/N_o greater than 5 dB at 1.544 Mbps, uncoded
  - Input Signal: -30 dBm $\pm$ dB, 50 Ω, 2:1 VSWR maximum (-5 dBm maximum composite level)
  - Receive Baseband Filtering: Maximally flat across passband with a 3-dB cutoff at the symbol rate/2 frequency and an attenuation no less than 36 dB/octave outside the passband. To reduce group delay effects in the passband, delay equalization will be employed
  - Receive Clock: Recovered from received signal, normalized to compensate for code rate
  - Bit Integrity: Less than one bit slip event per 24 hours.

3.1.5.4 Orderwire Modem to Earth Terminal IF Patch Interface (Interface D)

The interface between the orderwire modem and the earth terminal is shown in Figure 3-4. Its electrical, functional, and mechanical characteristics must be as follows:

- Baseband Interface: The modem baseband interface signal will be a digital PCM voice encoded at 64 kbps (DS-0) or a 64-kbps data signal
- Remote Interface: RS-232C 25 pin D-type for input and output
- Output Signal Level: -5 to -30 dBm, 50 ohms/75 ohms

- Data Clock: External-data rate $\pm$ 50 ppm; internal-data rate $\pm$ 10 ppm
- Demodulator Input: -30 dBm to -10 dBm, 50 ohms
- IF Connector: BNC.

3.1.5.5 Interface of Earth Terminal to Satellite Interface (Interface E)

The earth terminal will transmit and receive T1 and orderwire carriers in single channel per carrier (SCPC) mode using a frequency division multiple access (FDMA) scheme. Any one of the C-band domestic satellites (70^{o} to 140^{o}W) may be used. The operating frequencies are 5.925 to 6.425 GHz in the uplink and 3.7 to 4.2 GHz in the downlink. A combination of vertical and horizontal linear polarization will be used for transmit and receive frequency reuse.

3.1.5.6 TT&C to Satellite Interface (Interface F)

The TT&C interface to each satellite is fixed and cannot be practically changed. There is also an inherent incompatibility between satellites built by Hughes and by RCA. Enough similarity within a given manufacturer's satellites exists, however, to consider modifying two separate TT&C locations in order to allow each of these two sites to monitor and control all satellites within its family. Because of the uniqueness of these requirements, each manufacturer has been tasked to recommend an approach to achieve compatibility within each family. The results of these studies are contained in reports by RCA Astro Electronics and Hughes (Refs. 6 and 7).

3.1.5.7 NCC to Satellite Interface (Interface G)

The NCC will require an orderwire between itself and whichever TT&C location controls the satellite to be used to implement the system. This orderwire will be provided via a small earth terminal and associated orderwire terminal equipment. The interface of this small earth terminal will be the same as that for the commercial earth terminals except that the transmitted carrier will only carry 64 kbps of data on a single carrier.

3.1.5.8 Low-Cost Terminal to Satellite (Interface H)

The interface between the low-cost communications terminal and the satellite is to be the same as that for commercial earth terminals specified in subsection 3.1.5.5.

3.1.6 Operational and Organization Concepts

3.1.6.1 Concept of Operations

3.1.6.1.1 Pre-conditions to Employment. As stated in Section 3.1.2, above, the mission of the ICSS exists in a post-attack environment. The situation in this environment is expected to consist of several commercial satellites, communications earth terminals, and PSN switching nodes that have survived along with designated TT&C capabilities and an NCC capability. Although those facilities will have survived, they may not be in a configuration that is usable and may be unable to communicate with each other. It is in this worst-case configuration that the ICSS must be activated.

The decision to employ the ICSS must be made and the participants so notified. The notification will take place outside the boundaries of the ICSS, possibly through a message sent over the Emergency Broadcasting System (EBS). Regardless of the means of dissemination, the personnel assigned to the facilities must be available to receive the notification and to reach the sites.

3.1.6.1.2 Employment. Once on location, each site will establish site readiness by assessing damage, determining fuel supply for emergency power, activating back-up power (if required), assessing functional capabilities of the communications equipment on the site, and following the detailed plans and procedures specified for the situation at hand.

Once operational, the designated TT&C site will begin locating surviving satellites. The TT&C will assess the health and utility of each satellite in the interoperable family. This will include eliminating upsets and preparing the satellite so that it is capable of supporting an orderwire communications channel. After selecting a healthy satellite, the TT&C will step through the arc, transmitting a message through a predetermined frequency. The site will wait a specified time for responses from surviving earth stations on another predetermined frequency. In this case, the NCC and other TT&C sites are considered to be surviving earth stations.

The surviving earth terminals will establish their site readiness in the same way as the TT&C site. Each earth terminal will then test its own satellite. If that satellite is not operational or nonexistent, the earth terminal will step through the arc in a predetermined sequence until an operational satellite is found. Once found, the terminal will lock onto it and wait to be contacted by the TT&C site.

When contacted by the TT&C site, the earth terminal will be informed as to the satellite to be used for establishing the ICSS network. Upon receipt of this information, the earth terminals will repoint antennas and reestablish orderwire contact.

Once all earth terminals are pointing to the same satellite and the NCC has determined the required T1 connectivity, this information can be passed over the orderwire and T1 connectivity can be establisned. The concept intends that the NCC make the decision on connectivity but that the TT&C site direct the activation of the connectivity. This will free the NCC for decision making and coordination of activities rather than the details of circuit activations. Figure 3-5 depicts this basic concept.

3.1.6.2 Organization Concept

The ICSS addresses the enhancement of privately owned and controlled assets that will remain commercial while providing significant support to government users. Several PSN switch locations have been identified that will require improved inter-enclave connectivity using surviving C-band general services terminals. Appendix A identifies the PSN switch locations and the general services terminals, along with the locations and names of the carrier for each of the locations involved. The appendix also identifies the TT&C locations and the NCC location.

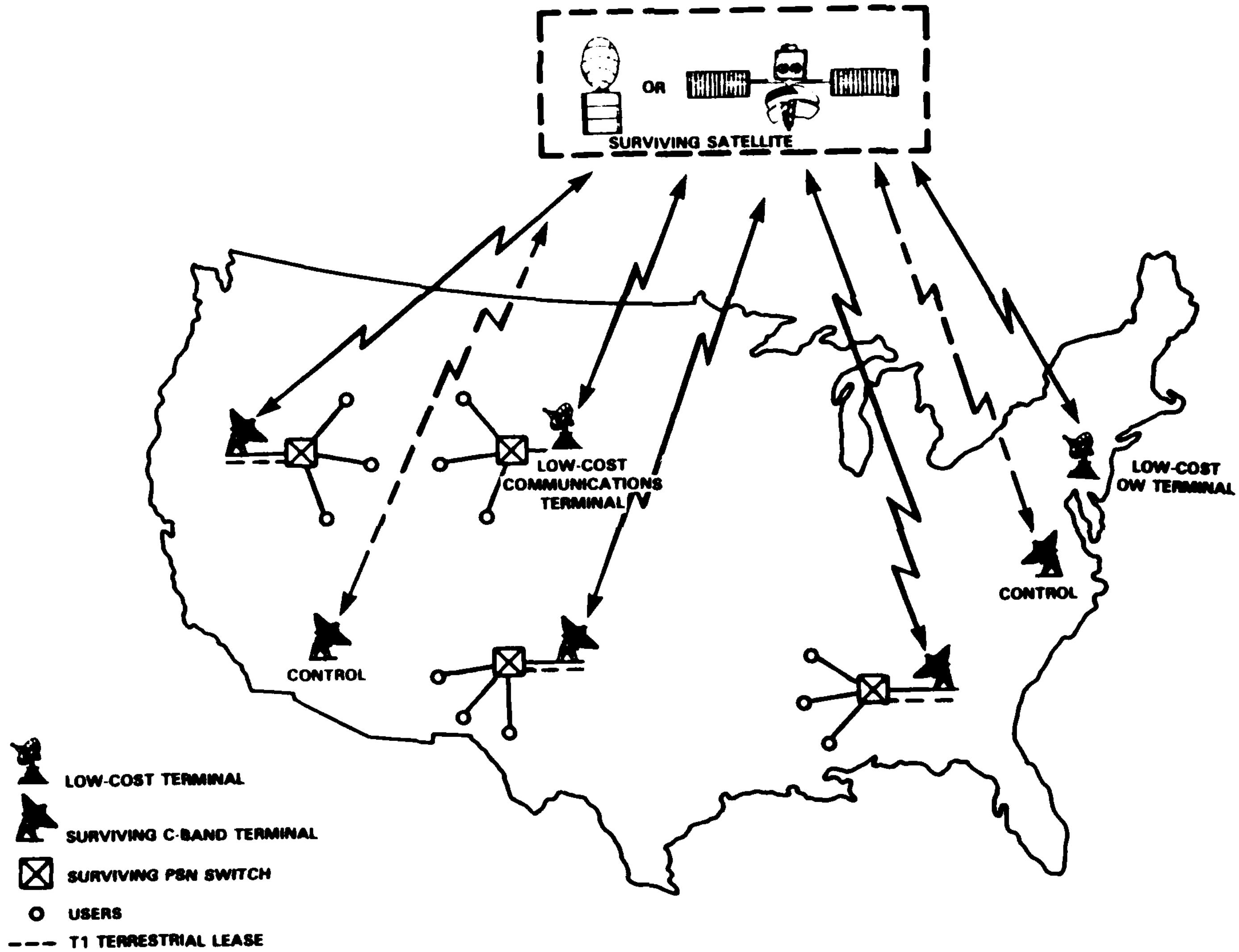

Figure 3-5. Concept of Operation for ICSS

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3.2 CHARACTERISTICS

3.2.1 Performance Characteristics

The following are the system (end-to-end) performance characteristics.

3.2.1.1 Bit Error Rate (BER)

To be compatible with T1 trunk performance, the BER must be less than 10^{-6} for a nominal channel between two earth station T1 modems, and less than 10^{-4} for a nominal channel between two switches. This will ensure that the T1 trunk does not reach the 10^{-3} alarm condition.

3.2.1.2 Loss of Frame/Cycle Slips

To be compatible with the local switch of the PSN, the slip rate requirement under various operating conditions must be as follows:

- Operation During Trouble Free Conditions:
  - Nominal clock slip rate = 0
- Operation During Trouble Conditions:
  - Nominal slip rate of less than 1 slip in 10 hours.

3.2.1.3 System Response Times

The following are the system response time performance objectives:

- T1 Leased Circuits: The contractor will make the circuits available for exercise use within 72 hours of notification by the government. The contractor will make the circuits available for non-exercise use as soon as possible after notification by the government, not to exceed 1 hour.

- Satellite Resources: The Satellite Earth Station Resources will be made available for exercise use on a noninterfering basis. The terminal will be made available for non-exercise use as soon as possible after notification by the government, not to exceed 72 hours.

- Orderwire and T1 Modem Tuning: The T1 and orderwire modems will be capable of being rapidly retuned by non-trained personnel. Retuning will be accomplished in 5 minutes or less.

3.2.1.4 Isolation

Orderwire and T1 modem: When not in service, the input and output port isolation on the modem will be greater than 100 dB.

3.2.1.5 End-to-End Delay

The end-to-end (PSN-to-PSN) delay will be less than 300 msec (i.e., not more than one satellite hop per connection).

3.2.1.6 Service Outages

A circuit outage is defined as any period of operational use time when (1) the link BER is greater than 1 part in 1,000,000; (2) transmission interruptions occur causing any circuit to be unavailable for government use; or (3) the telecommunications service is unable to maintain overall synchronization. Periods when the BER remains above 1 part in 1,000,000, the circuit is out of synchronization, or any other transmission interruptions last for less than 30 sec will be

considered for the purposes of calculating operational availability as an outage of 30 sec. All other outages will affect availability in the amount of their actual duration.

3.2.2 Physical Characteristics

The ICSS is a physically distributed communications system that spans the continental United States. It primarily employs existing commercial facilities whose physical characteristics are predetermined. Furthermore, the system requirements do not dictate any overall physical characteristics; however, there are constraints within the subsystems. In the case where equipment is to be added to existing facilities, the primary concern is the required physical space for the additional equipment. Sufficient space must be allocated at each location not only to accommodate the additional equipment but also to operate and maintain it. Where antennas are required to be repositioned, an unobstructed view of the new satellite is required, and there are physical constraints with regard to the routing of the terrestrial tails.

3.2.2.1 Terrestrial Tails

Terrestrial tail circuits will be used to connect earth stations to switches in the PSN. The physical routing of these circuits must be chosen to ensure a high probability that these paths will be operational in a post-attack envionment; therefore, routes that circumvent areas designated by the government will be utilized. These areas are specified in Appendix A.

3.2.2.2 Earth Stations

Line-of-sight clearance through the arc of interest must be ensured at all earth stations including TT&C and low-cost terminals. Any obstructions that block access to any portion of the arc must be specified and, if possible, removed. If an obstruction cannot be removed, an evaluation of the impact to the ICSS must be performed. If the impact is too large, an alternate location must be selected.

3.2.3 Reliability

Reliability is the probability that a system will perform in a satisfactory manner for a given period of time when used under specified operating conditions. It can be expressed as the mean-time-between-failures (MTBF), i.e., total system operating time divided by the number of system failures during that time period. However, in the case of the ICSS, reliability is an inherent part of the commercial system being incorporated into ICSS. For this reason, precise MTBF numbers for the system are not specified; however, the new equipment added to the system as well as any modifications to existing equipment must not degrade the reliability of the earth stations. Reliability figures for specific new subsystems to be incorporated into ICSS must be based on good commercial practice.

3.2.4 Maintainability

Maintainability combines features and characteristics of equipment design, job aids, and job support that facilitate the rapidity, economy, ease, and accuracy with which maintenance can be performed. The ICSS is highly constrained in the

equipment design area because off-the-shelf commercial equipment is to be used exclusively. Where choices exist regarding which commercial equipment to use (e.g., modems), modular design that is supported by automatic failure diagnosis to the LRU (lowest replaceable unit) will be selected. Where automatic fault diagnosis is not provided, sufficient test points, test equipment, and job aids will be provided to perform manual fault diagnosis to the LRU. The design objective is to obtain a mean time to repair (MTTR) of 30 min from the time the fault is identified within a particular earth station.

3.2.5 Availability

The inherent availability of a system is the probability that the system, when used under stated conditions in an "ideal" support environment, will operate satisfactorily at any point in time. It does not include preventive or scheduled maintenance, logistics delay time, or administrative delay time. The operational availability of a system is the probability that, when used under stated conditions in an actual operational environment, it will operate satisfactorily when required. It does include active maintenance time, logistics delay time, and administrative delay time.

In the case of ICSS, the system consists of existing commercial assets, for which the inherent availability is a given. This inherent availability places an upper bound on the operational availability of the system. Assuming that trained personnel are available to perform the necessary maintenance, the ability to obtain spare parts is likely to be the critical item that determines operational availability.

No hard requirement for operational availability has been specified for ICSS. It is suggested that a detailed site-by-site analysis be performed using inherent availabilty as a basis and determining the incremental costs of increasing the operational availability. This increase would be achieved primarily by providing on-site spare equipment/parts and increasing the training level of designated personnel. The on-site spares are necessary because of the probability of disruption to normal supply channels.

The ICSS consists of multiple point-to-point T1 connections as well as an orderwire network and control system. Availability is to be determined on the basis of the average of individual T1 connection availabilities end-to-end.

3.2.6 Environmental Conditions

3.2.6.1 Temperature

Any new equipment added to a given location must conform to the operational and storage temperature specifications of the equipment to which it will connect. Typical specifications for commercial equipment to be installed inside a building are as follows:

- Operational: $0^{o}C$ to $45^{o}C$
- Storage: $-30^{o}C$ to $85^{o}C$.

3.2.6.2 Relative Humidity

- Operational: 0 to 95 percent noncondensing
- Storage: 0 to 100 percent noncondensing.

3.2.6.3 EMP

The ICSS is not required to operate through periods of EMP disturbances. It is, however, required to operate after EMP resulting from high-altitude nuclear explosion. The precise EMP environment is not specified; however, certain EMP mitigation measures are suggested. A cost analysis on a site-by-site basis is required to determine specific mitigation measures.

The EMP considerations enhancements are not EMP hardening measures. They will, however, result in a higher probability that all circuits and functions necessary to support the desired level of operation in a post-attack environment will survive at the TT&C facilities and the fixed earth terminal facilities.

Four primary measures will be used. First, equipment added by the CSS program that are not part of daily facility operation will be maintained in an off-line condition and in a powered-down state. This will provide a high level of protection against EMP-induced damage. The second measure will involve protecting those equipments that cannot be maintained in a powered-down state or with all long lines disconnected. The protection measures to be considered include:

- Surge arrestors and/or filters for signal lines
- Filters and isolation transformers on power lines
- Waveguides flanges and RF seals at building waveguide penetrations.

The application of these measures is depicted in Figure 3-6. The third measure is to consider limited separation of selected

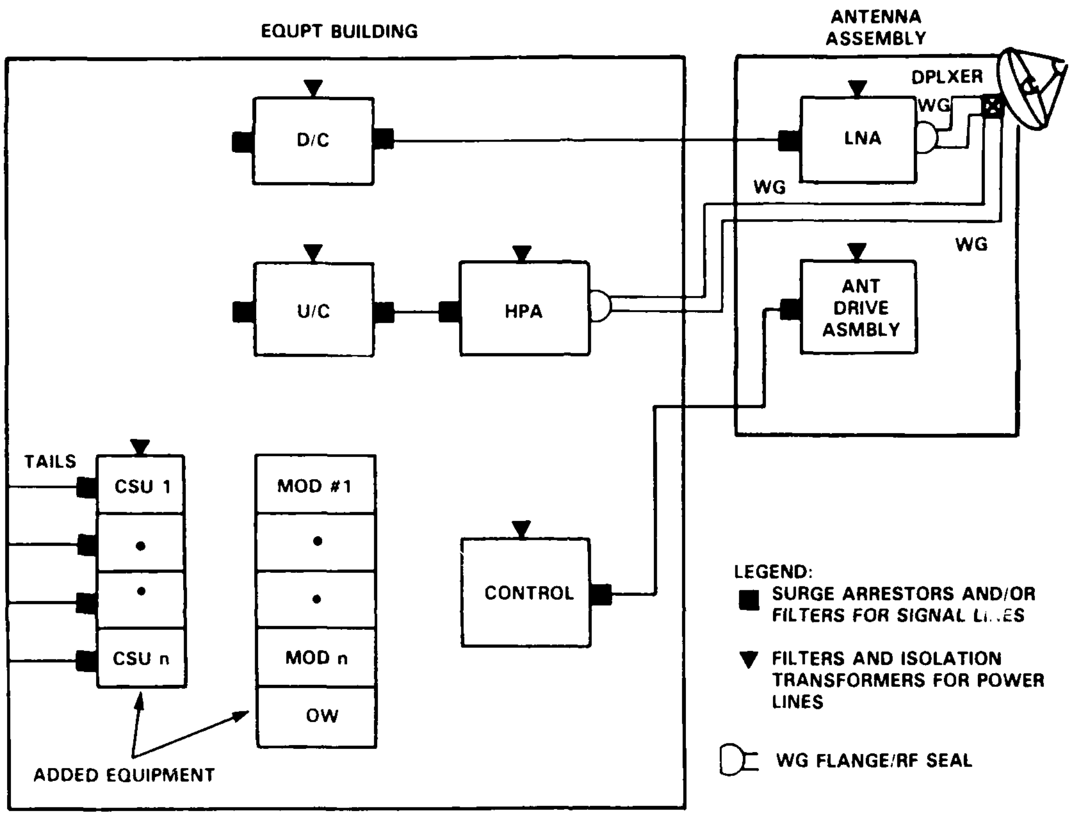

Figure 3-6. EMP Considerations

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cables from large cable bundles to reduce electromagnetic coupling. The fourth measure will involve creating an effective ground plane for each of the facilities. This will reduce the common mode voltage between equipments.

3.2.7 Transportability

Inasmuch as the ICSS will be installed within fixed facilities, there are no special transportability requirements except in the case of the low-cost earth terminals and their associated modems. The low-cost terminals must be capable of being packed, transported, and re-set-up by the personnel trained in the operation of the terminals without the use of mechanized loading equipment or other special tools. The purpose of such transportability is to allow these terminals to be used at (as yet undefined) test locations away from their primary location.

3.3 DOCUMENTATION

The following technical documentation is required.

3.3.1 Systems Manual

The systems manual is to be a top-level system document that follows the outline of this system specification, and describes what is actually implemented as part of the ICSS. Additionally, it will refer to more detailed technical literature.

3.3.2 Site Manual

Each site that is part of the ICSS will require a manual describing in detail how that particular site functions within the ICSS. It will include the definition of the specific equipment at that site which is part of ICSS.

3.3.3 Commercial Technical Literature

Appropriate commercial technical literature for each major equipment item will be provided. This literature should be sufficient to support maintenance requirements and include technical and operational information covering functional descriptions and capabilities, maintenance, and troubleshooting procedures, users manuals, circuit schematic drawings, specifications, test and adjustment data.

3.4 LOGISTICS

It is assumed in the ICSS operational environment that normal resupply channels have been disrupted. At best they will be severely slowed and may in fact be nonexistent. For this reason, sufficient on-site spare equipment must be available to meet anticipated spares requirements over an assumed operational period of at least 3 months. Specific spares requirements must be established on a site-by-site basis but should be based on an LRU concept as described in Section 3.2.4.

In addition to equipment spares, a detailed plan for resupply of fuel for back-up power generators must be developed since the availability of commercial power is questionable. These plans must be on a site-by-site basis.

3.5 PERSONNEL AND TRAINING

3.5.1 Personnel

The personnel to operate and maintain the ICSS are intended to be the same personnel who operate the specific facilities on a day-to-day basis. With the exception of the low-cost terminals locations, personnel at each location will be required to perform duties that require similar skill levels to those required on a daily basis in their normal duties. The low-cost terminals locations will require personnel to be designated to operate and maintain the terminals as an additional or substitute duty to be performed during test periods and during activation.

In addition to the common carrier designated personnel, a group of government personnel will be designated to replace or augment the common carriers' personnel should it be determined necessary. The required skill levels must be minimized by the use of well-labeled equipment racks and detailed written procedures. The skills required at the sites are indicated in Table 3-2.

Table 3-2. Personnel Skills Required

	EARTH STATIONS	TT&C	NCC
Satellite monitoring and control	O	X	O
Antenna alignment	X	X	X
OW ckt alignment	X	X	X
OW network control	O	X	X
T1 ckt alignment	X	O	O
Satellite terminal maintenance	X	X	X

X - Required
O - Not Required

3.5.2 Training

Because the ICSS is intended to be activated only in severe emergency situations, training of those personnel who are expected to activate and operate the system is critical. Both initial training and periodic refresher training will be required. Each location in the ICSS must develop a training program to cover the following areas:

- General system overview
- Detailed equipment operation
- Detailed equipment maintenance
- Initial activation procedures
- Sustained operational procedures
- System fault resolution.

Except for the general system overview, training requirements at the three types of sites (NCC, TT&C, and earth station) will vary greatly due to the different functions to be performed at each type of site. At the earth stations, while the functions to be performed are similar, the actual equipment and equipment layouts will vary--thus requiring customized training at each earth station as well.

In addition to individual site training, coordinated procedures training will be required on a system-wide basis to ensure that the individual actions at each site are implemented in a coordinated fashion to produce an operational system.

An overall training plan must be developed, and each site must certify to the NCS that site-unique training has been completed.

3.6 FUNCTIONAL AREA CHARACTERISTICS

This section provides the necessary detail to more fully define the requirements within each functional area of the ICSS. These functional areas are depicted on Figure 3-4. They are:

- Terrestrial T1 circuits
- Standard T1 modem
- Orderwire subsystem
- Commercial earth stations
- Low-cost communications terminal
- TT&C earth terminals
- Domestic commercial satellites
- Low-cost orderwire terminal.

3.6.1 Terrestrial T1 Circuits

The contractor will provide for the extension, by terrestrial facilities, of the T1 circuits from their earth station to toll switches in the PSN. Routes that circumvent areas designated by the government will be utilized, as specified in Appendix A. The preferred option for the provision of the circuits and associated customer service units (CSUs) is to lease from common carriers. New construction is permitted where required. A combination of carriers and carrier facilities is permitted.

The functional interface between the PSN and the terrestrial link is shown in Figure 3-7. This interface must be compatible with the standard 24-channel DS1 interface. (See Ref. 5, AT&T Technical Advisory #32.)

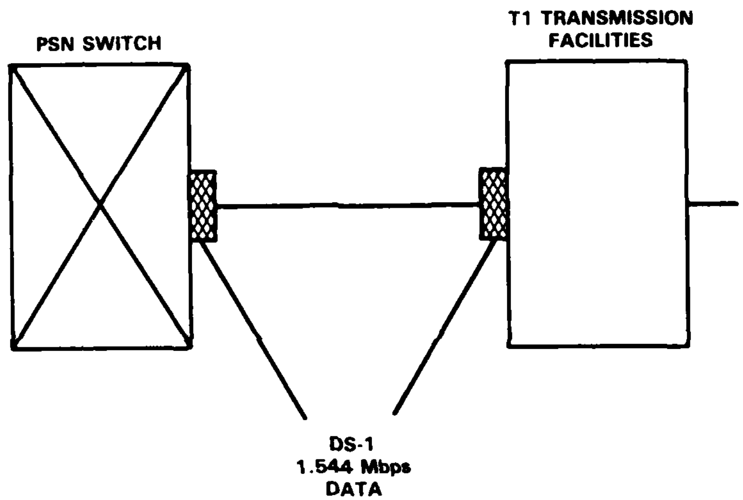

Figure 3-7. PSN to T1 Transmission Interface

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The terrestrial link will be capable of transmitting a standard T1 carrier 1.544 Mbps line format, consisting of twenty-four 8-bit words and one framing bit for a total of 193 bits/frame at a frame rate of 8 kHz.

The electrical and mechanical characteristics of this interface will be as specified in Section 3.1.5.

The DS1 interface will provide a capability for a loop back both at the PSN switch and the earth station. This loop back will be the "standby" operating mode of the T1 extensions. Furthermore, upon receipt of notification of activation of the ICCS, the loop-back mode must be reconfigured rapidly (less than 10 minutes) to pass live traffic from the PSN to the earth station, and from the earth station to the PSN.

The maintenance of the physical integrity of the routes will include, as necessary, continuous tests/continuity alarms and such provisions as the deletion from a trunk inventory and recordkeeping (TIRKS) or TIRKS-like data base of the trunk group(s) carry the T1 circuits. As a minimum, a summary alarm indication will be provided (by a contact closure) at the CSU in the earth terminal connecting to the tail circuits.

3.6.2 Standard T1 Modem

3.6.2.1 Functional Description

T1 "off-the-shelf" modems will be installed in the earth terminal. Each modem will use one full duplex channel between that terminal and a compatible terminal. The modems must be prepositioned, off line at the earth terminal, and will provide the necessary function to interface between the DS1

signal of a T1 trunk termination and the IF converter equipment at the earth terminal. A functional diagram of the T1 modem is given in Figure 3-8.

3.6.2.2 Interface Definition

The electrical and mechanical interfaces must be in accordance with subsections 3.1.5.2 and 3.1.5.3; however, when the equipment is not in operation, it is to be isolated from all operational connections by at least 100 dB.

3.6.2.3 Performance

The modem must meet or surpass the following specifications: The bit energy-to-noise ratio (E_b/N_o) that is required to achieve a 10^{-6} BER with a rate 3/4 sequential decoder is 6.7 dB. The modem alone, without coding, will provide operation within 1 dB of theoretical for BERs in the range of 10^{-1} to 10^{-6}. These performance measurements are with transmit and receive IF converted back to back.

The modem must be tunable in a range from 52 to 88 MHz. The tuning is to be accomplished without the need for special tools and/or test equipment. Positive indication will be given as to the frequency selected.

3.6.3 <u>Orderwire Subsystem</u>

3.6.3.1 Functional Description

An orderwire will provide an orderwire capability between earth stations. A separate modem, telephone, and PCM voice encoder and decoder will be required. A functional diagram of the orderwire subsystem is given in Figure 3-9.

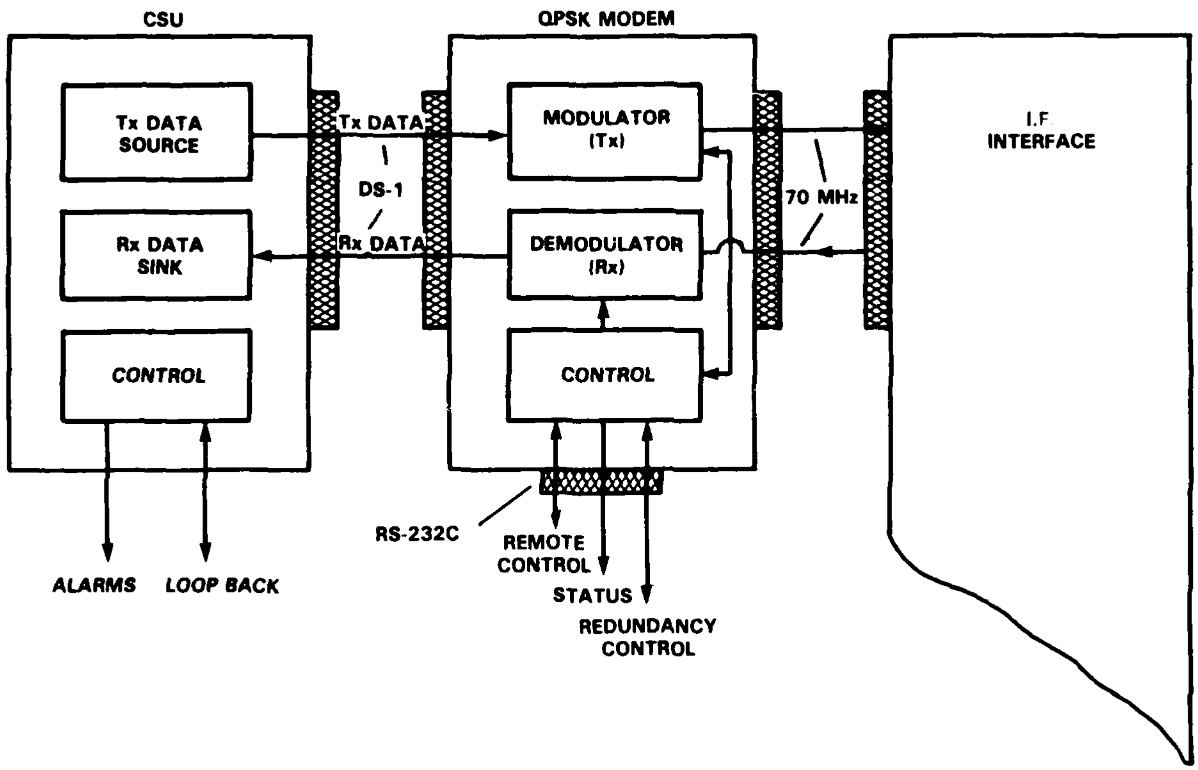

Figure 3-8. T1 Modem Functional Diagram

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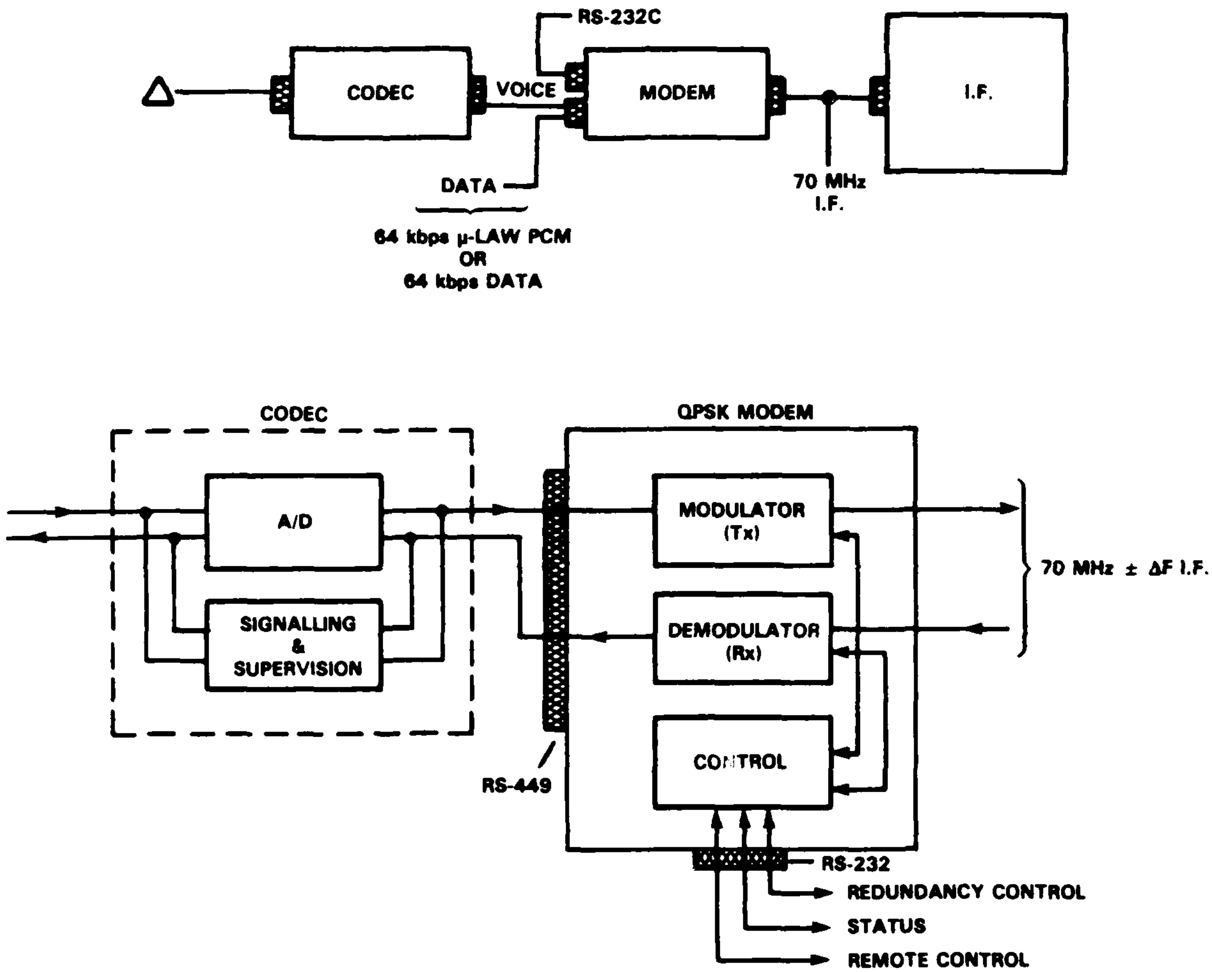

Figure 3-9. Orderwire Functional Diagram

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The telephone will provide 4-kHz analog voice and signaling to the encoder. The encoder will accept 4-kHz analog voice and signaling and provide 64-kbps PCM to the orderwire modem.

The orderwire modem must accept 64-kbps data and provide the earth station equipment with a QPSK signal at IF (70 MHz). The interface to the earth station is to be as discussed in subsection 3.1.5.3. The modem also must be capable of accepting 64-kbps data instead of digital voice through a standard RS-449 port.

The orderwire capability will provide for a common channel to be shared by all earth terminals in a broadcast mode.

3.6.3.2 Interface Definition

The orderwire modem must have an external RS-232 interface that will allow for remote control, signaling, and status indicators. The physical and electrical interfaces must be in accordance with Section 3.1.5. The orderwire subsystem also must provide for selective ringing of distant end instruments by means of a two-digit code.

3.6.3.3 Performance

The orderwire modem muse meet or surpass the same performance requirements as the T1 modem specified in subsection 3.6.2.3.

3.6.4 Commercial Earth Stations

3.6.4.1 Functional Description

Most of the commercial earth stations to be utilized for the ICSS are trunking earth stations. The trunking earth station processes the majority of the trunking traffic of a common carrier. Hence, the terminal encompasses several antennas and several up and down chains of RF and IF equipment.

The specification in this section establishes general criteria for the common carriers to enhance the required number of up and down chains in each earth station that will be used. Therefore, no new RF/IF equipment is needed. The specification reflects the emphasis of utilizing the existing RF/IF equipment with few enhancements, if required, to ensure interoperability among common carriers.

3.6.4.2 Functional Block Diagram

Figure 3-10 is a block diagram that shows the up and down chains of an earth station. The number of up and down chains depends on the number of transponders that must be accessed to support emergency traffic. Appendix A specifies the number of up and down chains required at each earth station.

3.6.4.3 Interface Definition

The interface is at the IF level, i.e., the input to the up converter and the output of the down converter.

3.6.4.4 Performance

The performance parameters of the earth station equipment are specified to satisfy the minimum requirements for the

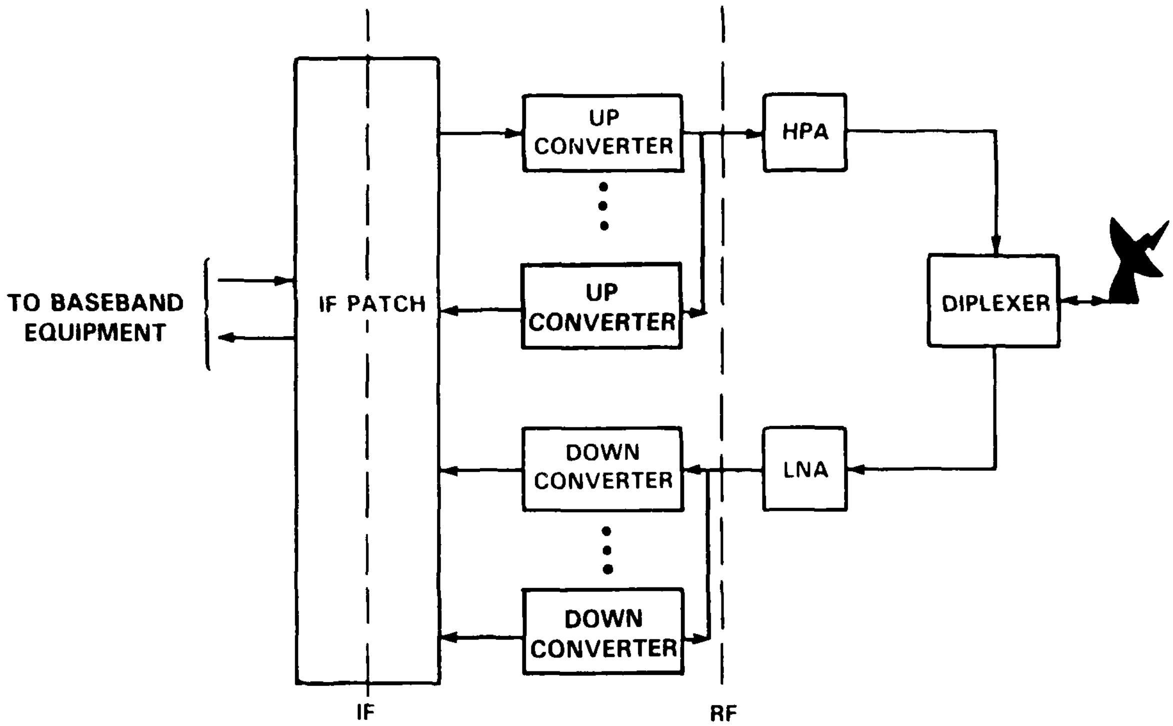

Figure 3-10. Earth Station Functional Area Diagram

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transmission of information with good quality. Most existing equipment will satisfy the performance parameters; otherwise, slight modifications to the existing equipment may be needed.

3.6.4.4.1 Typical Antenna Subsystem. This will entail the following characteristics:

Electrical

Parameter	Receive	Transmit
Frequency	3.7-4.2 GHz	5.925-6.425 GHz
Gain (mid band)	51.0 dBi	55.0 dBi
Radiation Pattern	Meet FCC Requirements	
Power Handling		5 kW
G/T	32.0 dB K°	-

Mechanical

Antenna Diameter:	11 m
Antenna Travel:	
- Elevation	5° to 90°
- Azimuth	70° to 140°
Number of Ports:	4

Environmental

Wind Loading (operational):	80 mph
Temperature Range:	-20°F to 125°F

3.6.4.4.2 Amplifier Subassembly. The LNA will be 500-MHz wide and capable of operating in the band 3.7 to 4.2 GHz. The noise temperature will be less than 60°K. The HPA will be 500-MHz wide and capable of operating in the band 5.925 to 6.425 GHz. If a narrow bandwidth HPA is used, it must be readily tunable over the entire band in 40-MHz steps.

3.6.4.4.3 Frequency Converter. Up converter performance specifications are:

- Frequency Selection: Synthesizer tuned
- Input
  - Frequency: 70 ± 18 MHz
  - Impedance: 50/75 ohms unbalanced
  - Return Loss: 23 dB
- Output Frequency: 5.925 to 6.425 GHz.

The down converter performance specifications are:

- Frequency Selection: Synthesizer tuned
- Input Frequency: 3.7 to 4.2 GHz
- Output
  - Frequency: 70 ± 18 MHz
  - Impendance: 50/75 ohms unbalanced
  - Return Loss: 23 dB.

3.6.4.5 Availability

Availability is defined as the probability that the up or down RF/IF chains equipment, when used under stated conditions in an ideal support environment (i.e., readily available tools, spares, maintenance personnel), will operate satisfactorily at any point in time as required. It excludes preventive or scheduled maintenance actions, logistics, delay time and administrative delay time and is expressed as

$$A = \frac{MTBF}{MTBF + MTTR} \quad , \text{where}$$

MTBF = mean time between failures

MTTR = mean time to repair.

This availability is sometimes called inherent availability.

The RF/IF equipment availability depends on the number of equipment and redundancy switches connected in series as well as the equipment MTBF. It is estimated that the inherent availability for a single RF/IF chain is 0.9990156 for the up chain and 0.9993803 for the down chain.

3.6.5 Low-Cost Communications Terminal (LCCT)

3.6.5.1 Functional Description

The LCCT is to operate with commercial C-band satellites at frequencies of 3.7 to 4.2 GHz (transmit) and 5.925 to 6.425 GHz (receive). In addition, it must be interoperable with the existing fixed-site satellite terminals specified in Section 3.6.4. It will provide three single channel per carrier (SCPS) channels; one channel will be provided through the orderwire modem specified in Section 3.6.2 at 64 kbps, and the other two channels will be provided through the T1 modem specified in Section 3.6.3.

3.6.5.2 Functional Block Diagram

A block diagram of the terminal, shown in Figure 3-11, depicts the functional relationships. Three nominal 70-MHz carriers are translated to the transmit frequency. The output of the up converters are summed and applied to the input of the power amplifier. The output power level will be variable from zero to maximum wattage either locally or remotely. At the antenna, the signal will be filtered and properly polarized for transmission to the satellite.

The received signal from the satellite is to be separated from the transmit signal by selecting the proper signal polarization. It will be filtered and amplified by a very low-noise, high-quality amplifier. The receive signal will then be power split and applied to similar frequency down converters.

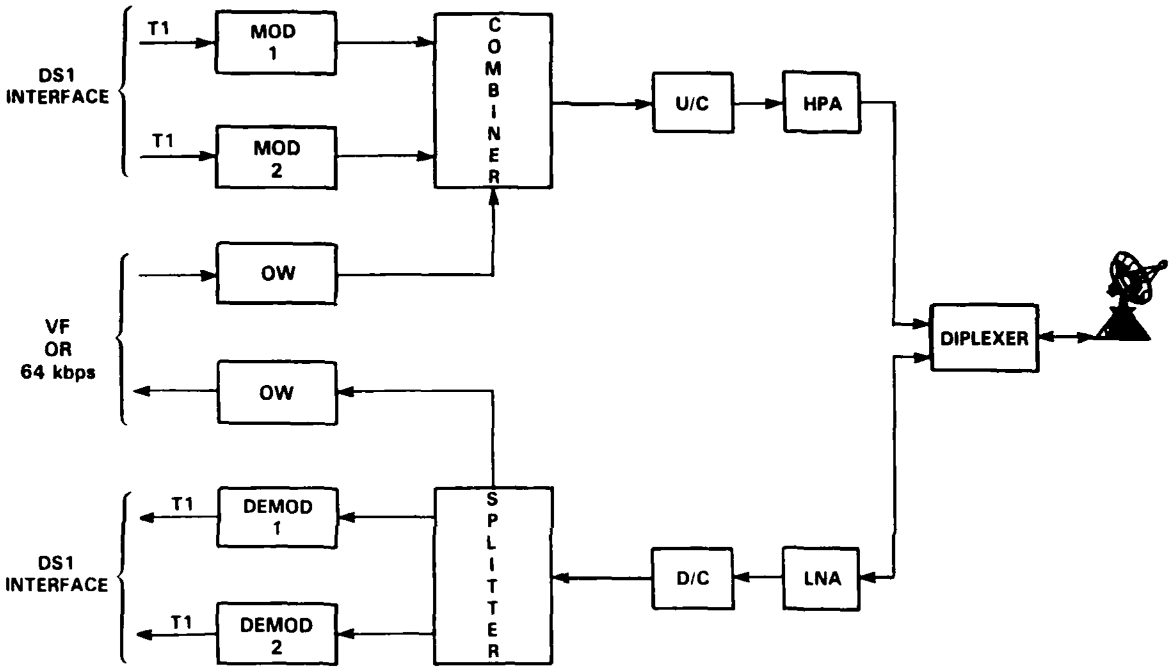

Figure 3-11. Low Cost Communications Terminal Diagram

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The tunable down converters will select a portion of the receive frequency band and translate it to a nominal 70-MHz IF.

Both a local and a remote Status and Control Unit will be provided to perform control and monitor functions for the terminal subsystems.

The power control and distribution system is to receive 120 VAC 60-Hz primary line voltage and distribute it to the rest of the system.

3.6.5.3 Interface Definition

The earth terminal to modem interface will be at 70-MHz intermediate frequency with the following electrical and mechanical interfaces:

- Up Converter
  - Connector: BNC
  - Input: -5 to -30 dBm at 50 Ω or 75Ω (factory set) 2:1 VSWR maximum
  - IF Center Frequency: 70 MHz ±1 kHz
  - IF Bandwidth: 36 MHz.
- Down Converter
  - Connector: BNC
  - Output: -30 dBm ± 10 dBm at 50 Ω or 75 Ω (factory set) 2:1 VSWR maximum
  - IF Center Frequency: 70 MHz ±1 kHz
  - IF Bandwidth 36 MHz.

The PSN to earth terminal interface is specified as follows:

- I/O Data and Clock: Standard DS1 levels
- Connector--PSN to Earth Terminal Shelter: Standard DS1
- Connector--Earth Terminal Shelter to Modem: 37 pin D-type (connector to modem).

3.6.5.4 Performance

The terminal must meet the following performance requirements:

- Transmit Frequency (range/accuracy): 5.925 to 6.425 GHz

- Receive Frequency (range/accuracy): 3.7 to 4.2 GHz

- Transponder Agility: Remote/manual control over entire transponder center frequency range

- Pointing Error: $\pm.35^{\circ}$ in 25 mph wind; $\pm.45^{\circ}$ in 30 mph wind; $\pm.75^{\circ}$ in 40 mph wind

- EIRP: 58 dBW

- Polarization Adjustment:

  - Manual: 360 deg
  - Motorized: ± 90 deg

- Antenna Travel (motorized and manual):

  - Elevation: 5 deg to 90 deg
  - Azimuth: 180 deg.

3.6.5.5 Physical Characteristics

The transportable terminal must be capable of operation on a flatbed semi-tractor trailer (size TBP). Antenna and shelter are to be mounted and secured on the trailer during operation. Sufficient shelter space must be provided to house all terminal equipment excluding antennas and LNA subassemblies.

Two PSN-to-earth terminal interface connectors as specified in subsection 3.6.5.3 must be provided on the external wall of the shelter, be protected from weather when not in use, and be easily accessible by maintenance personnel. Modem to external connector capability within the shelter is to be provided by the earth terminal contractor.

3.6.5.6 Reliability

The low-cost communications terminal must have a system MTBF of 1,000 hours, where a failure is defined as any malfunction that causes the loss of communications on any one or more channels while the terminal is operational.

3.6.5.7 Maintainability

The low-cost communications terminal must support failure diagnosis to the LRU such that the MTTR all failures is 1 hour or less.

3.6.5.8 Availability

System inherent availability must be at least 99.9 percent.

3.6.5.9 Environmental

3.6.5.9.1 Temperature. The required temperature specifications are:

- Operational: -30°C to +40°C
- Storage: -40°C to +85°C.

3.6.5.9.2 Humidity. The specifications regarding humidity are:

- Operational: 10 to 90 percent noncondensing
- Storage: 0 to 100 percent noncondensing.

3.6.5.9.3 De-icing. De-icing capability both manually and automatically activated will be provided to enable continuous earth terminal operation through snow and icing conditions.

3.6.5.9.4 Wind Loading. The wind loading requirements are:

- Operational: 60 mph
- Survival: 85 mph - no ice.

3.6.5.9.5 Atmospheric Conditions. The transportable terminal must be designed to operate continuously with no performance degradation in atmospheric environments containing salt, pollutants, and corrosive contaminants as found in coastal and industrial areas.

3.6.5.10 Transportability

Transportability requirements for the LCCT are specified in Section 3.2.7.

3.6.6 TT&C Earth Terminals

3.6.6.1 Functional Description

A typical ground control network consists of a satellite control center (SCC) and two TT&C stations. The TT&C terminals are usually widely separated to maximize system availability.

The SCC is responsible for planning satellite operations, generating command lists to implement these plans, and processing telemetry data to monitor the health and configuration of the satellite.

In the normal configuration, commands will be developed at the SCC and be transmitted to the TT&C station for relay to the satellite. The TT&C station will collect and monitor satellite telemetry and forward it to the SCC for storage and analysis. However, in case of major SCC equipment failure or loss of data lines, a TT&C station may be used to originate spacecraft commands and to receive and process telemetry.

3.6.6.2 Functional Block Diagram

A typical TT&C ground segment is shown in Figure 3-12. The real-time control computer performs all the telemetry processing functions (including averaging and archiving data in files for the orbital operations computer and for updating CRT displays), performs the spacecraft command functions of formulating commands and verifying execution, and interfaces the spacecraft controller and the earth station hardware.

The telemetry processing subsystem will include the receiver to convert the IF telemetry/ranging output to baseband for input to the range tone processor, or to the subcarrier demodulator where the telemetry bit stream is recovered from

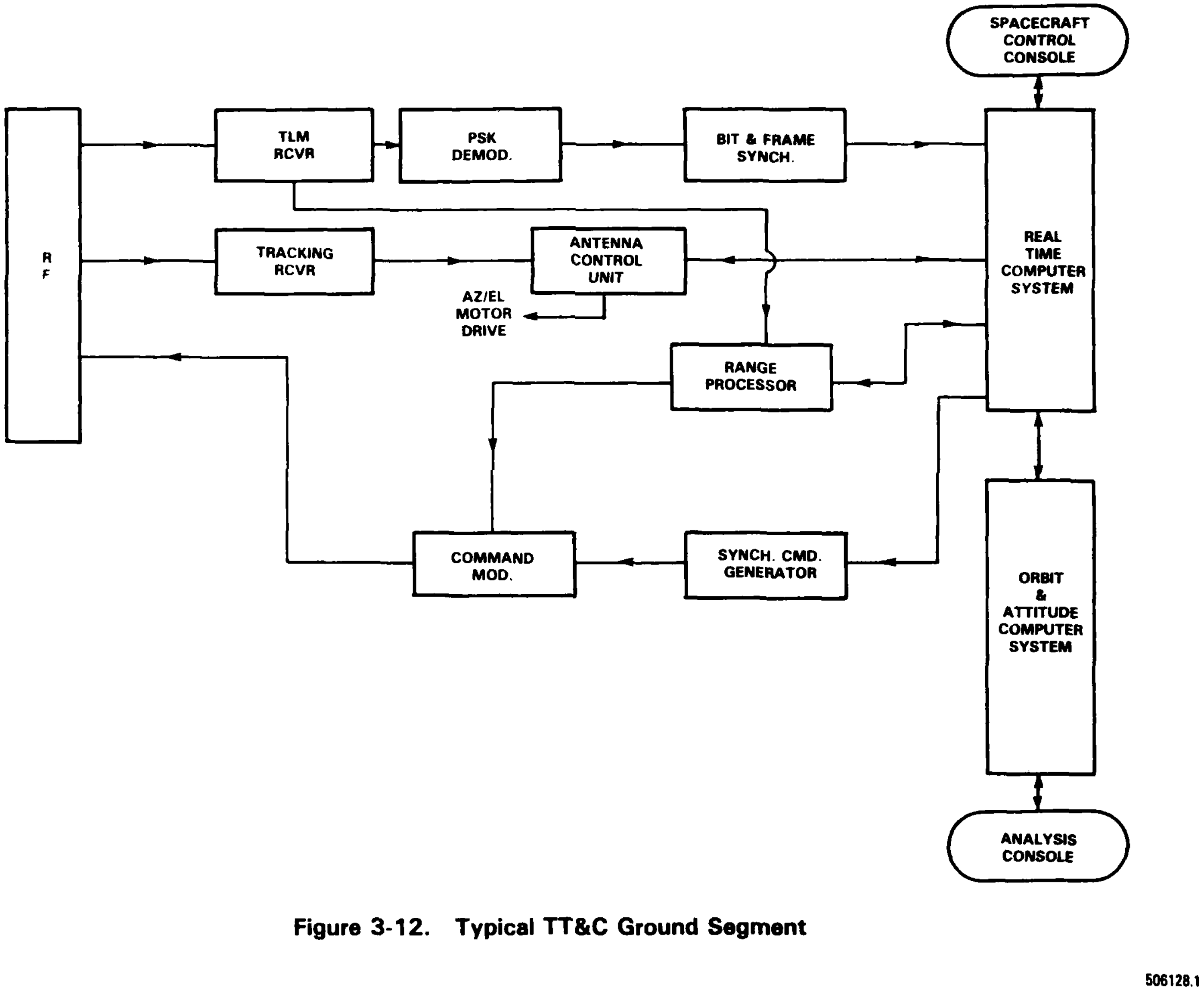

Figure 3-12. Typical TT&C Ground Segment

its subcarrier. The telemetry bit stream will be bit synchronized and frame synchronized for input to the real-time computer system, where the data can then be displayed.

The command processing subsystem will include a synchronous command generator (SCG) to convert computer commands into the spacecraft command format. The command modulator will be driven by the range processor and the SCG, for which it will route commands to the up converter at IF.

The ranging subsystem will consist of the range tone processor and the ranging software, which will measure the phase delay of the timed sequence of tones looped through the satellite.

The orbit and attitude computer system will compute spacecraft orbit and attitude based on data received from the real-time computer.

3.6.6.3 Interface Definition

Typical interface parameters to the satellite control channel are specified in subsection 3.6.7.2.

3.6.6.4 Performance

The TT&C site must be capable of maintaining the selected satellite within a 0.5 deg orbital box. The intent is to specify performance at each of two TT&C locations such that each location can monitor and control all satellites in one family. This will include the test equipment requirements (e.g., spectrum analyzer) for monitoring communications channel status once the satellite has been stabilized.

3.6.7 Domestic Commercial Satellites

This section presents an overview of the characteristics of currently available commercial satellites. The discussion is limited to those satellites operating at C-band frequencies and providing coverage to CONUS. These are the satellites that will be available for activation of the ICSS.

3.6.7.1 Functional Description

The set of commercial satellites providing CONUS coverage include those residing in an equatorial arc bounded in the west at 134^{o}W and in the east at 74^{o}W. These limits are defined by the FCC and result from their minimum recommended antenna elevation angle within CONUS. Each satellite occupies a slot at geosynchronous orbit (approximately 37,500 km) and is separated by a minimum arc of 2 deg from neighboring slots. This location is typically maintained within 0.1 deg of the designated location.

Services currently provided by commercial satellite systems include common carrier, private and government networks, video broadcasting, and distribution. Several types of modulation techniques are employed including frequency modulation (FM), mainly for voice and analog data, and quadrature phase shift keying (QPSK) for digital data, which typically ranges from a few kilobits per second to tens of Megabits per second. Multiple access is accomplished via frequency division- and time division-multiple access (FDMA and TDMA) with FDMA predominating.

Table 3-3 contains a listing of commercial satellites. The columns identify the longitudinal (^{o}W) location, the operator, the satellite name, manufacturer, number of transponders, launch date, and life expectancy, respectively.

Table 3-3. Domestic Commerical Satellites
(Source: Ref. 8)

LOC	OPERATOR	NAME	MANU-FACTUTER	NO.OF XPDRS	LAUNCH (YEAR)	LIFE (YEARS)
72	RCA	SATCOM IIR	RCA	24	83	8
74	HUGHES	GALAXY II	HUGHES	24	83	9
83	RCA	SATCOM IV	RCA	24	82	10
87	AT&T	COMSTAR D3	HUGHES	24	78	7
91	WESTERN UNION	WESTAR III	HUGHES	12	79	7
93.5	HUGHES	GALAXY III	HUGHES	24	85	9
99	WESTERN UNION	WESTAR IV	HUGHES	24	82	10
112.6	RCA	SATCOM II	RCA	24	76	8
120	GTE	SPACENET I	RCA	12	84	7
123	WESTERN UNION	WESTAR V	HUGHES	24	82	10
127	AT&T	COMSTAR D4	HUGHES	24	81	7
128	AMSAT	ASC-1	RCA	16	85	9
131	RCA	SATCOM IIIR	RCA	24	81	9
134	HUGHES	GALAXY I	HUGHES	24	83	10
139	RCA	SATCOM IR	RCA	24	83	10

3.6.7.2 Interfaces

This section addresses the interface requirements for commercial satellites, in particular the TT&C operations interface. As indicated in Table 3-3, Hughes and RCA currently manufacture all commercial C-band satellites. Hughes spacecraft are stabilized via spin-rotation, whereas the RCA spacecraft are 3-axis stabilized. Because of their different stabilization techniques, each class of spacecraft imposes unique requirements for TT&C. Therefore, to provide TT&C interoperability between the two classes of satellites,

separate TT&C resources are required. Furthermore, each commercial operator generally employs different frequencies and coding techniques for command and control, which imposes additional requirements for TT&C interoperability among users of the same satellite class. Examples of TT&C formats are shown in Table 3-4.

Table 3-4. Typical Control Parameters of Domestic C-Band Satellites

SATELLITE/ MANUFACTURER	COMMAND		TELEMETRY	
	FREQ (MHz)	FORMAT	FREQ (MHz)	FORMAT
WESTAR/ HUGHES	6420	3 TONE FSK/FM	4198.25 (V) 4198.75 (V) 4190.25 (V)	PCM/PSK/PM PAM/FM/PM
COMSTAR/ HUGHES	5927	3 TONE FSK/FM	3700.5 (H) 4198.0, 4198.5 4199.0, 4199.5 (V)	PCM/PSK FM
SATCOM/RCA	6423.5	3 TONE FSK/FM	3700.5 (CH) 4199.5 (V)	FM/PM PAM/FM/PM
SPACENET/RCA	6422	3 TONE PCM/FSK/ FM	3700.5 (H) 4199.5 (V)	PCM/FM FM

3.6.7.3 Performance

The commercial satellites of interest operate at uplink and downlink carrier frequencies of approximately 6 GHz and 4 GHz, respectively. In general, the spacecraft contain 12 physical transponders, each providing approximately 36 MHz of usable bandwidth. Most, however, employ orthogonal polarization, which effectively doubles the number of transponders to 24; the notable exceptions are the hybrid satellites carrying both C-band and Ku-band payloads: AMSAT-1 and SPACENET-1. The effective isotropic radiated power (EIRP) provided by each transponder is in the range of 32-34 dBW. These data are summarized in Table 3-5 for a typical C-band commercial satellite.

Table 3-5. Typical C-Band Satellite Characteristics

PARAMETER	VALUE
Transponder Bandwidth	36 MHz
Effective No. of Transponders	24 (via othogonal polarization)
EIRP	32-36 dBW (edge of beam)
G/T	-7 dBW/^{O}K
Polarization	V,H; H,V
# Voice Channels/Burst Rate Per Transponder	400-600/60 Mbps
Frequencies (GHz)	
Transmit	3.7-4.2
Receive	5.925-6.425

3.6.8 Low-Cost Orderwire Terminal (LCOT)

3.6.8.1 Functional Description

The LCOT will operate with commercial C-band satellites at frequencies of 3.7 to 4.2 GHz (transmit) and 5.925 to 6.425 GHz (receive). In addition, it must be interoperable with the existing fixed-site satellite terminals specified in Section 3.6.4. It is to be capable of transmitting and receiving the SCPC 64-kbps signal from the orderwire modem specified in Section 3.6.2.

3.6.8.2 Functional Block Diagram

A block diagram of the terminal, shown in Figure 3-13, depicts the functional relationships. A nominal 70-MHz carrier will be translated to the transmit frequency. The output of the up converter will be applied to the input of the power amplifier. The output power level must be variable from zero to maximum wattage either locally or remotely. At the antenna, the signal will be filtered and properly polarized for transmission to the satellite.

The received signal from the satellite will be separated from the transmit signal by selecting the proper signal polarization. It then will be filtered and amplified by a very low-noise, high-quality amplifier. The receive signal will be applied to a frequency down converter. The tunable down converter will select a portion of the receive frequency band and translate it to a nominal 70-MHz IF.

Both a local and a remote Status and Control Unit must be provided to perform control and monitor functions for the terminal subsystems.

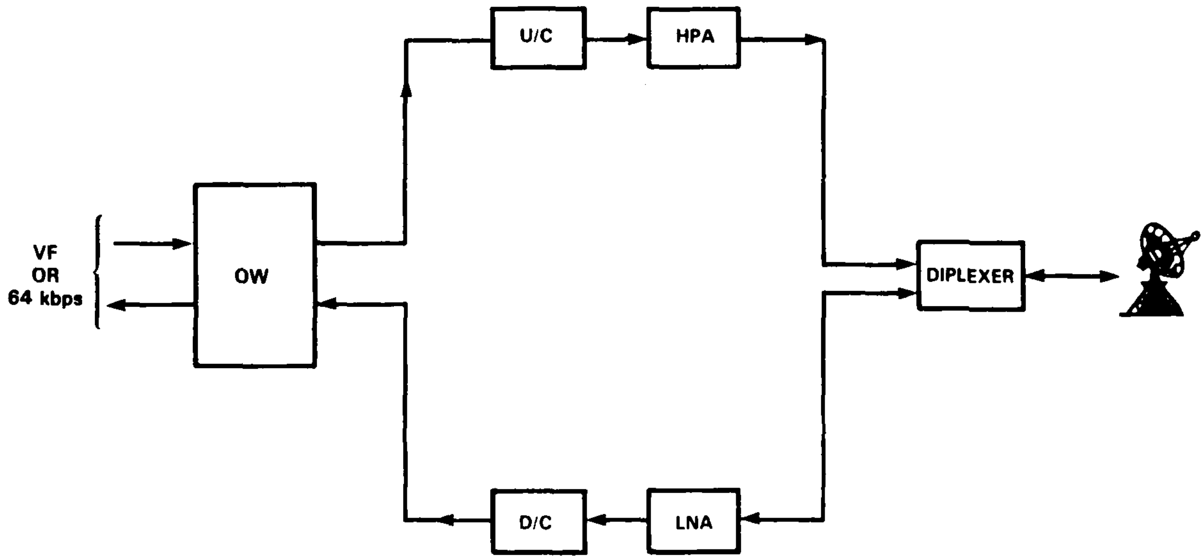

Figure 3-13. Low Cost Orderwire Terminal Diagram

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The power control and distribution system is to receive 120 VAC 60-Hz primary line voltage and distribute it to the rest of the system.

3.6.8.3 Interface Definition

The earth terminal equipment must provide an interface configuration compatible with the orderwire modem interface specifications outlined in Section 3.6.2. The earth terminal to modem interface must be at 70-MHz intermediate frequency with the following electrical and mechanical interfaces:

- Up Converter
  - Connector: BNC
  - Input: -5 to -30 dBm at 50 Ω or 75 Ω (factory set) 2:1 VSWR maximum
  - IF Center Frequency: 70 MHz ±1 kHz
  - IF Bandwidth: 36 MHz.
- Down Converter
  - Connector: BNC
  - Output: -30 dBm ± 10 dBm at 50 Ω or 75 Ω (factory set) 2:1 VSWR maximum
  - IF Center Frequency: 70 MHz ±1 kHz
  - IF Bandwidth 36 MHz.

The orderwire baseband interface signal must be digital PCM encoded voice at 64 kbps.

3.6.8.4 Performance

The terminal must meet the following performance requirements:

- Transmit Frequency (range/accuracy): 5.925 to 6.425 GHz
- Receive Frequency (range/accuracy): 3.7 to 4.2 GHz
- Transponder Agility: Remote/manual control over entire transponder center frequency range
- Pointing Error: $\pm .35^{\circ}$ in 25 mph wind; $\pm .45^{\circ}$ in 30 mph wind; $\pm .75^{\circ}$ in 40 mph wind
- EIRP: 45 dBW
- Polarization Adjustment
  - Manual: 360 deg
  - Motorized: ± 90 deg
- Antenna Travel (motorized and manual):
  - Elevation: 5 to 90 deg
  - Azimuth: 180 deg.

3.6.8.5 Physical Characteristics

The LCOT must be capable of operating on a flatbed semi-tractor trailer (size TBP). Antenna and shelter will be mounted and secured on the trailer during operation. Sufficient shelter space must be provided to house all terminal equipment excluding antennas and LNA subassemblies.

3.6.8.6 Reliability

The LCOT will have a system MTBF of 1,000 hours, where a failure is defined as any malfunction that causes the loss of communications on any one or more channels while the terminal is operational.

3.6.8.7 Maintainability

The LCOT must support failure diagnosis to the LRU such that the MTTR all failures is 1 hour or less.

3.6.8.8 Availability

System inherent availability is to be at least 99.9 percent.

3.6.8.9 Environmental

3.6.8.9.1 Temperature. The temperature requirements are:

- Operational: $-30^{\circ}C$ to $+40^{\circ}C$
- Storage: $-40^{\circ}C$ to $+85^{\circ}C$.

3.6.8.9.2 Humidity. Requirements concerning humidity are:

- Operational: 10 to 90 percent noncondensing
- Storage: 0 to 100 percent noncondensing.

3.6.8.9.3 De-icing. De-icing capability, both manually and automatically activated, must be provided to enable continuous earth terminal operation through snow and icing conditions.

3.6.8.9.4 Wind Loading. Wind loading specifications are:

- Operational: 60 mph
- Survival: 85 mph - no ice.

3.6.8.9.5 Atmospheric Conditions. The transportable terminal must be designed to operate continuously with no performance degradation in atmospheric environments containing salt, pollutants, and corrosive contaminants as found in coastal and industrial areas.

3.6.8.10 Transportability

Transportability requirements for the LCOT are specified in Section 3.2.7.

CHAPTER 4. QUALITY ASSURANCE PROVISIONS

As with any new system, the transition of the ICSS from development to operational status requires a full series of acceptance and assurance tests to verify its operation and specification compliance. This chapter presents a concept for ICSS testing and a framework for the development of a detailed test plan.

In addition to acceptance tests, periodic system operational tests will be conducted to exercise the ICSS and to ensure its availability.

4..1 RESPONSIBILITIES

The NCS, as the cognizant agency for the ICSS, will have the final acceptance authority for all equipment purchased as part of the system. To this end, the NCS will approve detailed tests plans and procedures that are developed and submitted by the contractor(s). The NCS, in addition, will have the final release authority for the entire ICSS following successful completion of all testing. The NCS will appoint a director of test and field trials who will have the responsibility of coordinating and witnessing all functional and operational tests.

In general, acceptance testing will be conducted by the equipment contractors and the common carrier personnel and will follow the approved test plans and procedures. Contractors will furnish all test equipment and personnel required to complete the tests. Test will be witnessed by a representative of the NCS to authenticate and verify the results.

System availability tests, to be conducted periodically after system acceptance, will be coordinated by the NCS, which will furnish the necessary manpower and resources.

4.2 TESTING REQUIREMENTS

Acceptance testing will proceed in two distinct phases. Phase I testing will verify the proper functioning of the components to be provided as part of the ICCS as well as their overall functional interface compatibility with existing earth station equipment. Phase II testing will be concerned with field testing the operational performance of the integrated system and will be conducted on common carrier premises to simulate the operational environment.

Component tests in Phase I should be designed to exhaustively verify the component's compliance with specifications. Separate tests for each specification are preferable. Table 4-1 contains a generic outline for individual test plans. The components envisioned to undergo these tests are: leased T1 link, T1 interface, T1 modem, and frequency synthesizer.

Table 4-1. Test Plan Outline

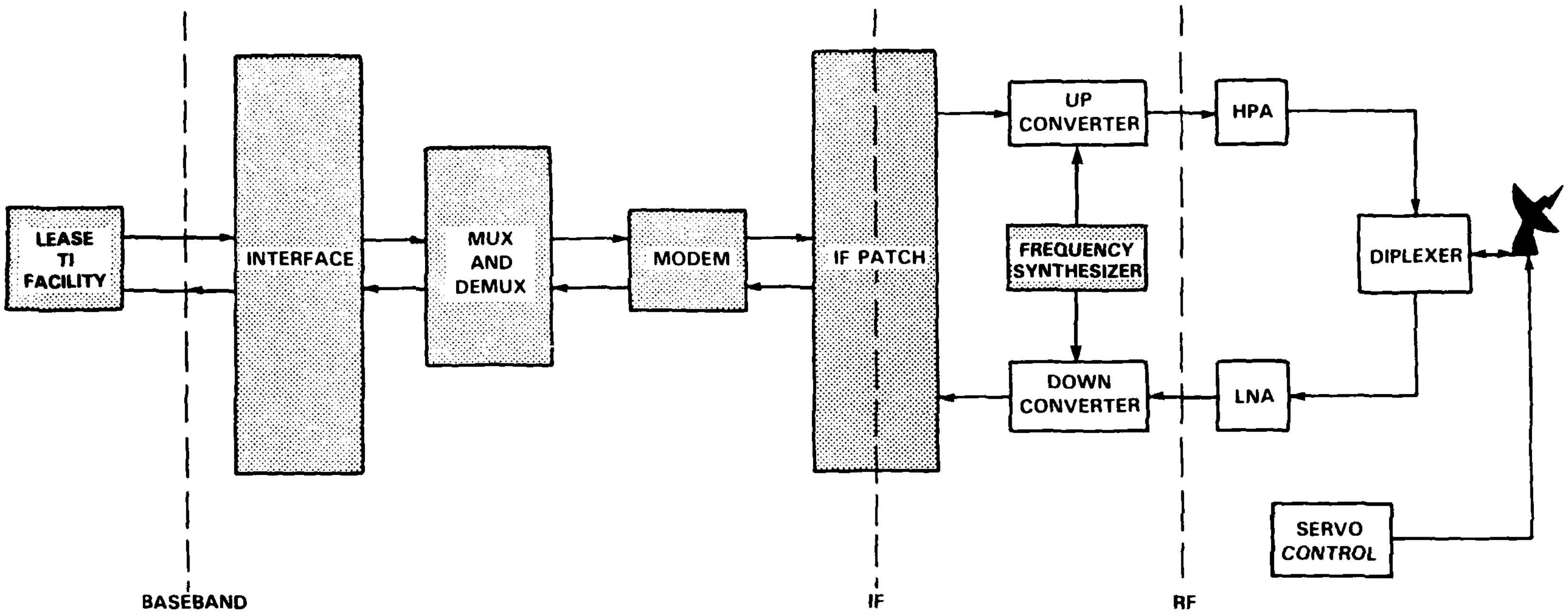
A.	<u>OBJECTIVE</u>: State which specification is verified by this test
B.	<u>TEST EQUIPMENT</u>: List of required test equipment
C.	<u>SET-UP</u>: Explain or diagram connections between component under test and test equipment; include test equipment configurations/settings
D.	<u>PROCEDURES</u>: Provide a step-by-step procedure for completion of the test
E.	<u>EXPECTED RESULTS</u>: Explain what constitutes a pass/fail result for the test

Figure 4-1 depicts a generalized block diagram of the ICSS. The first phase of testing will verify the functional operation of all components individually and integrated as an entire single-ended (through RF) system.

Prior to integrating any new component into the common carrier's facilities, complete functional and interface acceptance testing must be performed in order to verify its compliance with specifications. This series of tests may be performed at the equipment contractor's facilities and must be satisfactorily completed to ensure compatibility.

A hierarchical scheme for testing is envisioned in which component and subsystem functional verification tests are performed at each level from baseband through RF. To illustrate this concept, Figure 4-2 outlines the configuration for the series of tests to be performed. When successful, this phase of testing involves no RF radiation, and procedures can be conducted at a common carrier's test facility or at any suitable earth station. The equipment used in this phase of testing must be identical in function and interface to that at a contractor earth station where the operational system is to be deployed.

The next phase of acceptance testing will commence after the successful completion of component interface and functional testing. Phase II testing will verify complete system operation through end-to-end testing performed at the contractor premises. The objective is to provide a test envionment which, to the extent possible, emulates the actual perceived operational enviornment through the use of equipment procured for the CSS program, existing common carrier equipment, contractor equipment and common carrier personnel. This will require the use of contractor facilities including



NOTE: SHADED COMPONENTS ARE TO BE ADDED UNDER PROGRAM;
UNSHADED COMPONENTS ARE EXISTING EQUIPMENT AT EXISTING
ICSS EARTH STATION.

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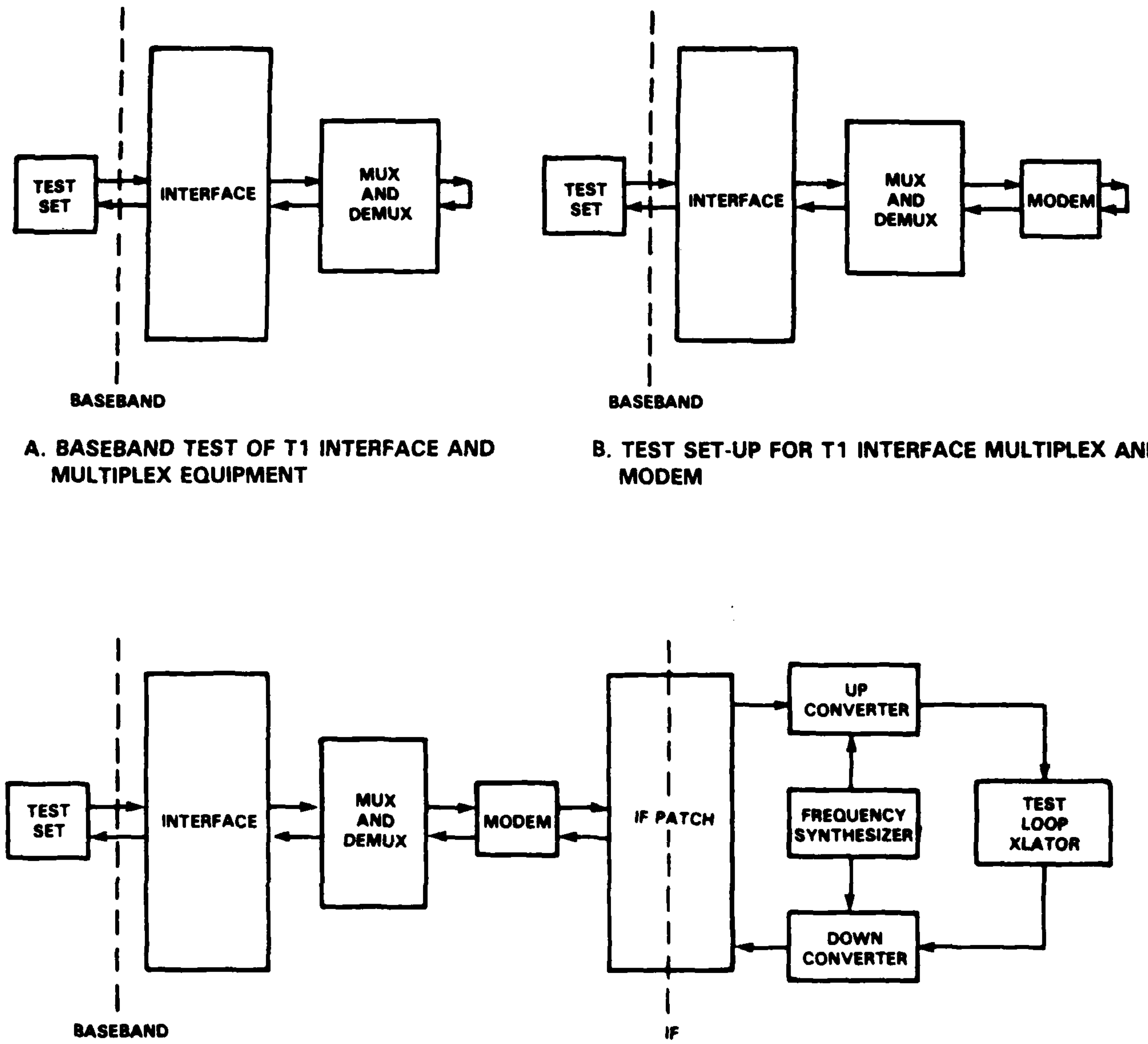
Figure 4-1. Generalized ICSS Diagram



A. BASEBAND TEST OF T1 INTERFACE AND MULTIPLEX EQUIPMENT

B. TEST SET-UP FOR T1 INTERFACE MULTIPLEX AND MODEM

C. COMPLETE SINGLE LEASED CSS SYSTEM TEST SET-UP

Figure 4-2. Hierarchical ICSS Test Configurations for Phase I

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appropriate earth station equipment and satellite capacity. Use of such resources may require advance scheduling to prevent the testing from affecting the earth station's day-to-day operations. This scheduling will be done by the contractors responsible for conducting the tests and will be subject to the availability of the appropriate equipment and personnel.

Phase II tests should be designed to measure system performance, in terms of voice quality, circuit completion delay, BER, and other measures of merit to be determined. Test plans should include observing the effects of varying degrees of degradation (e.g., attenuating the uplink signal and adding noise to the downlink signal). Tests should also be designed to measure human factors such as system set-up time and ease of implementation. Table 4-2 lists the factors that should be measured by the operational tests. To the extent possible, test plans should follow the outline shown in Table 4-1.

As previously stated, the in-place ICSS will be tested periodically to ensure adequate functioning and availability. In addition, these tests will serve as exercises to train personnel in the system's operation. A plan will be developed for these tests that thoroughly exercises the system and ensures its operational availability. The test plan will contain procedures for system set-up including cabling, level adjustment, and antenna adjustment (if necessary). System performance will be measured through standard methods developed for operational acceptance tests including circuit completion times, BER, voice quality, and performance under full load conditions. Test equipment and other necessary resources (e.g., transmission equipment, satellite capacity) will be provided by the common carrier. Tests will be scheduled by the NCS, subject to the availability of manpower and resources.

Table 4-2. Operational Acceptance Test Factors

1. SYSTEM SET-UP

   A. Cabling

   B. Uplink/Downlink Power Levels

      -- IF
      -- RF

   C. Link Performance Verification

      -- E_b/N_o, E_c/N_o

2. SYSTEM PERFORMANCE

   A. Performance Curves (Waterfall Curves)

   B. Circuit Availability

      -- Voice and data

   C. Circuit Completion Delay

   D. BER

   E. Voice Quality

   F. System Capacity

      -- Circuit completion rate

      -- Performance (e.g., BER under fully loaded conditions)

   G. Operation Under Degraded Conditions

      -- Performance with uplink attenuation/downlink added noise

      -- Performance thresholds (e.g., minimum required levels to maintain voice and data circuits)

   H. Frequency Agility

      -- Synthesizer performance

3. HUMAN FACTORS

   A. Time to Set-up

   B. Ease of Implementation

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